BULLETIN

Of The

American Association

Of

Petroleum Geologists

Volume II.

Chas. H. Taylor, Editor

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1918

CONTENTS.

OFFICERS FOR 1918

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405 Stewart Bldg., Houston, Texas

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Morgantown, W. Va.

W. E. WRATHER, *Secretary-Treasurer*
Dallas, Texas

CHARLES H. TAYLOR, *Editor*
324 Baum Bldg., Oklahoma City, Okla.

THE CONSTITUTION

Article I.—NAME

This association shall be called THE AMERICAN* ASSOCIATION OF PETROLEUM GEOLOGISTS.

Article II.—OBJECT

The object of this association shall be the promotion of the science of geology among the men engaged primarily in the geology of petroleum and gas.

Article III.—MEMBERS

Section 1.—Any person actively engaged in the work of the Petroleum Geologist, studying petroleum geology, teaching this subject or related subjects, or connected with a State Geological Survey in the capacity of geologist or assistant geologist is eligible to active membership in the American Association of Petroleum Geologists, providing; that he is a graduate of an institution of Collegiate or University standing in which institution or institutions he has done his major work in geology, or, if he shall have carried on studies in such institution or institutions, and shall have published a creditable book on some phase of geology, or an article on some geological subject in some periodical of generally accepted scientific standing, or whose standing in the profession has been favorably passed upon unanimously by the executive council.

Section 2.—Any person having completed as much as twenty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this shall be eligible to associate membership in the American Association of Petroleum Geologists, providing that at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing or shall be engaged in geological work.

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*At the 1918 annual meeting the name American was substituted for Southwestern.

Section 3.—Active and associate members shall be elected to the association according to the qualifications outlined in sections one and two, providing that the applicant properly fills out the regular application blank, including the signatures of two active members of the association, and that such application be approved by at least three of the members of the executive committee of the association as provided for in Article IV, sections 1 and 4.

Section 4.—Associate members shall enjoy all the privileges offered by the association save that the associate members may not hold any office, sign the application for new members, nor vote on constitutional amendments.

Article IV.—OFFICERS

Section 1.—The officers of the association shall consist of a president, a vice-president, a secretary-treasurer, and an editor-in-chief, who together shall constitute the executive committee of the association.

Section 2.—The officers shall be elected annually from the association at large.

Section 3.—No man shall hold the office of president or vice-president for more than two years in succession.

Section 4.—The executive committee shall consider all nominations for membership and pass on the qualifications of the applicant, shall have the control of the association's work and property, shall determine the manner of publication and pass on all materials presented for publication, and may call special meetings when and where thought advisable and arrange for the affairs of the same.

Article V.—MEETINGS

The annual meeting shall be held at a time most convenient for the majority of the members at a place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting be read, all society business transacted, scientific papers read and discussed, and officers for the ensuing year shall be elected.

Article VI.—AMENDMENTS

The constitution may be amended at any annual meeting of the association by a vote of three-fourths of the active members present at the time voting on the amendment.

Article VII.—PUBLICATION

The proceedings of the Annual Meeting and the papers read shall be published in an annual bulletin. This shall be under the immediate supervision of the Editor-in-Chief, assisted by a Publication Committee, consisting of three members to be appointed by the President.

BY-LAWS

DUES.—The regular dues of an active member of the association shall be five dollars. The yearly dues of an associate member of the association shall be three dollars. These annual dues are to be paid to the secretary-treasurer on or about January first for the year ending the following December.

Any member in arrears for more than two years shall be dropped from the roll of members providing he shall have been informed of his deficiency by the secretary-treasurer, a second time after an interval of six months.

The payment of the yearly dues entitles the member to receive without further charge, one copy of the proceedings of the association for that year.

AMENDMENTS

These by-laws may be amended by the vote of three-fourths of the active members present at any annual meeting.

ACTIVE MEMBERS

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DeGolyer, E.
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Hughes, V. H.
Hummel, E. W.
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Snider, L. C.
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Williams, D. W.
Willis, S. M.
Wrather, W. E.
Woodruff, E. G.
Wright, A. T.
Wright, H. F.

ASSOCIATE MEMBERS

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Donoghue, David
English, L. E.
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Grove I. H .
Hans, Oscar E.
Henley, A. S.
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Jillson, W. R.
Lowe, H. J.
Minor, H. E.
Morgan, Harold
Mulky, Francis P. *
Witteven, G. W.
Ramsey, R. H.
Scott, W. W.

*In the service af the United States Army.
‡Dece d.

Proceedings *of the* Third Annual Meeting *of the* American Association *of* Petroleum Geologists

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OKLAHOMA CITY MEETING, FEBRUARY 15 and 16, 1918

The third annual meeting of the American Association of Petroleum Geologists, was called to order at 9 a. m., February 15, in the Lee-Huckins Hotel assembly room by President J. Elmer Thomas.

The report of the president was given. Owing to the absence of the Secretary-Treasurer, Marice G. Mehl, his report was not given at this time. A motion was adopted to refer the Secretary-Treasurer's report to an auditing committee. I. Perrine was appointed chairman of this committee.

The report of the Editor was given. Motion was made and adopted to appoint a Constitution committee, and F. Aurin was appointed chairman of this committee. Motion was carried to give the remaining copies of the Bulletin of the Association to new and other members who had not received one.

Motion was made and carried that members who had paid the 1917 dues, be allowed to vote at this meeting.

Motion carried that the election of officers be made by informal ballot, at the business session of February 16.

There being no further business to come up at this time, the regular program of the Technical session was given.

TECHNICAL SESSIONS

The Technical Sessions were held in the assembly room of the Lee-Huckins hotel and the following program was given, on February 15 and 16th.

The Distribution of Underground Salt Water and Its Relation to the Accumulation of Oil and Gas. By Professor Roswell H. Johnson.

Review of Past Year's Developments of Geological Interest in the Gulf Coast District. By Alexander Deussen.

Geological Conditions in Central Kansas. By Dr. Irving Perrine.

The Value of Petroleum Geology in the Mid-Continent Fields. By Dr. Edward Bloesch.

Review of Past Year's Developments of Geological Interest in Kentucky. By J. R. Pemberton.

Geologic History of the Crystalline Rocks of Kansas. By Dr. Raymond C. Moore.

The Geology of Cuban Petroleum Deposits. By E. DeGolyer.

New Development for Oil and Gas in Oklahoma During the Past Year and Its Geologic Significance. By Geo. E Burton.

On the Migration of Petroleum Through Sedimentary Rocks. By A. W. McCoy.

Review of Past Year's Developments of Geologic Interest in Northern Texas. By W. E. Wrather.

A Contribution to the Stratigraphy of the Red Beds. By D. W. Ohern.

Review of Oil and Gas Development in Northern Louisiana. By Mowry Bates.

PUBLIC SESSION

On Friday evening, February 15, a popular program was given at the First Methodist church. The public was invited to hear a discussion of the work of the United States Fuel Administration by the Assistant Director, Thomas A. O'Donnell. Following this talk Dr. I. C. White of Morgantown, West Virginia, gave a highly entertaining lecture on the Gusher wells of Old Mexico, illustrated by moving pictures of the Huasteca Petroleum Company's Cerro Azul No. 4, the largest oil well in the world. Professor J. F. Kemp illustrated an excellent lecture on Geology Applied to Engineering and James H. Gardner gave a well illustrated lecture on The Mammoth Cave of Kentucky.

NOONDAY MEETING

The Association met Friday noon as guests of the Oklahoma Oil and Mining Association at a luncheon in the Lee-Huckins Hotel dining room. Short but valuable talks were given by Professor R. D. Salisbury, Professor J. F. Kemp and Dr. I. C. White.

BUSINESS SESSION

February 16th at 9 a. m.

The meeting was called to order by the president. The report of the auditing committee was given and adopted.

The report of the constitution committee was given as follows: That the constitution be adopted as printed on pages 7 and 9 inclusive, of the Bulletin of the Association, with certain recommendations and amendments.

(1) It was recommended that the name of the Association remain the Southwestern Association of Petroleum Geologists.

(2) That section "1" of Article "III" be changed to read as follows: Any person actively engaged in the work of the Petroleum Geologist, studying petroleum geology, teaching this subject, or related subjects, or connected with a State Geological Survey in the capacity of geologist or assistant geologist is eligible to active membership in the Southwestern Association of Petroleum Geologists, providing; that he is a graduate of an institution of Collegiate or University standing in which institution or institutions he has done his major work in geology, or, if he shall have carried on studies in such institution or institutions, and shall have published a creditable book on some phase of geology, or an article on some geological subject in some periodical of generally accepted scientific standing.

Section 2.—Any person having completed as much as twenty hours of geology__________________in a reputable institution of collegiate or university standing, or who has done full work equivalent to this, shall be eligible to associate membership in the Southwestern Association of Petroleum Geologists,____________or shall be engaged in geology * * * *.

It was further recommended that Article VI be amended to read: The constitution_________________of the active membership present at the time of voting on the amendment. Motion was made and carried, that the above amendments to the constitution be adopted.

In addition to the above amendments, a motion was made and carried that Article 1 of the constitution be amended to read: This association shall be called the American Association of Petroleum Geologists, and that the word *American* be substituted in all other parts of the constitution in place of the word *Southwestern.*

Motion was made and carried that Section 1 of Article III of the constitution be amended by adding to the 3rd paragraph as follows: or, whose standing in the profession has been favorably passed upon unanimously by the executive council.

PAPERS AND DISCUSSIONS

REVIEW OF DEVELOPMENTS IN THE GULF COAST COUNTRY IN 1917

By Alexander Deussen, *Houston, Texas.*

The more notable developments of geologic interest in the Gulf Coast Country during 1917, have taken place at Iberia, in Louisiana, and Damon Mound and Goose Creek, in Texas. Attention will be directed to these and incidentally to several other localities.

New Iberia, Louisiana

The New Iberia district is located in Iberia Parish, Louisiana, on Tete Bayou, about 6 miles east of New Iberia.

Pronounced escapes of petroleum gas and so-called "paraffin beds" were discovered in this vicinity in the summer of 1916, and these showings lead to the drilling, which resulted in the discovery. There is no topographic feature present, except possibly a peculiar meander of Bayou Teche, which would indicate the presence of a salt dome, the ground being practically flat, and the soil being similar to that of the surrounding area.

Work of drilling was begun in December, 1916, by the New Iberia Oil Company and the Gulf Refining Company. Well No. 1 of the former company on the Bolivar farm was completed in February, 1917. It encountered a hard sandstone with much pyrite at 1,008-1,025 and 1,043-1,070, both beds containing oil and gas. Below this 8 feet of hard sandstone was encountered, and below this the drill went a few feet into rock salt. A log of this well follows:

Log of Well of New Iberia Oil Company, Bolivar No. 1, New Iberia, Louisiana.

	Thickness Ft.	Depth Ft.
Blue surface clay	70	70
Gray sand and gas	110	180
Water gravel	225	405
Crust of sand rock	1	406
Soft gumbo and boulders	29	435
Hard gumbo	44	479
Hard gumbo	58	537
Packed sand	153	690
Crystallized sand, pyrite	36	726
Soft gumbo, streaks of crystallized sand and pyrite	44	770
Hard gumbo	29	799
Hard gumbo	22	821
Hard gumbo	29	850
Crystallized sand	20	870
Hard gumbo	66	936
Dry sand and gas	4	940
Very hard gumbo	8	948
Oil sand	12	960
Hard blue gumbo	3	963
Hard gumbo	45	1,008
Pyrite, oil and gas	17	1,025
Hard black gumbo	18	1,043
Pyrite, oil and gas	27	1,070
Hard sandrock	2	1,072
Cap rock	6	1,078

The oil encountered was green in color and tested 23.8° gravity. It was not a typical "cap rock" oil, which made the value of the find doubtful at the time. For a few days this well pumped about 125 barrels of oil, and then in the course of a month or so dwindled to 2 or 3 barrels, and was finally abandoned in April, 1917.

This find, however, started an active drilling campaign. The Gulf Company's Staiti-Bernard No. 1 was located about

one-half mile east of the discovery well. This was drilled to a depth of 2,855 feet. It came in May 24, 1917, making about 1,500 barrels of oil. The well settled to 50 barrels in the course of a month and pumped continuously for six or seven months.

Gulf Company's No. 1, Sabatier, an off-set to the preceding well, was completed September 23, 1917, at a depth of 2,849 feet. It came in making 25 (?) barrels, and is still pumping. These were the only two producing wells in the district out of 19 wells drilled.

Other tests were as follows: (See Map Fig. 1).

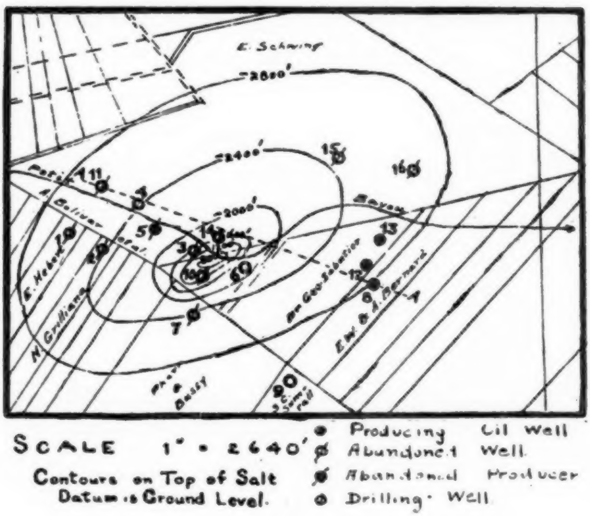

FIG. 1. MAP OF NEW IBERIA OIL FIELD.

IBERIA PARISH, LOUISIANA.

LIST OF WELLS.

1. Sun Co., No. 1, Hebert.
2. Hincy No. 2, Grilliana.
3. New Iberia No. 2, Bolivar.
4. Gulf No. 1, Schwing.
5. New Iberia No. 1, Bolivar.
6. Gulf No. 1, Ledet.
7. Gulf Staiti No. 1, Loisel.
8. Gulf Staiti No. 1, Bernard.
9. Paraffin No. 1, Sumrall.
10. New Iberia No. 1, Ledet.
11. Gulf No. 2, Schwing.
12. Gulf Sabatier No. 1.
13. Gulf Sabatier No. 2.
14. Gulf Staiti-Schwing No. 2.
15. Gulf Schwing No. 3.
16. Gulf Staiti-Schwing No. 1.

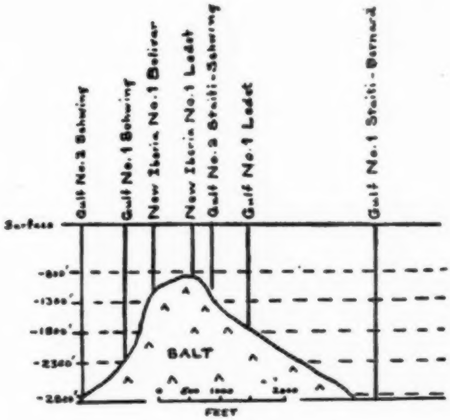

FIG. 2.

SECTION ACROSS NEW IBERIA DOME.

ALONG LINE A-A OF FIG. 1.

TABLE OF WELLS DRILLED AT NEW IBERIA.

(To January, 1918)

Name of Well.	Date of completion or abandonment	Depth	Remarks
New Iberia Oil Co.			
No. 1. Bolivar	February 6, 1917	1,078	Producer; abandoned.
No. 1. Ledet	April 1917	856	Salt at 856.
No. 2. Bolivar	July 3, 1917	1,710	Showed some oil and so-called cap-rock; abandoned.
Gulf Refining Co., of Louisiana.			
No. 1. Schwing	March 10, 1917	2,150	Showed some oil; abandoned.
No. 2. Schwing	June 1917	2,658	Abandoned in salt.
No. 3. Schwing	August 13, 1917	2,202	Abandoned.
No. 1. Staiti-Loisel	April 16, 1917	2,409	Salt.
No. 2. Staiti-Loisel	August 13, 1917	3,270	No show.
No. 1. Reynard	August 13, 1917	3,560	No show of importance.
No. 1. Staiti-Bernard	May 24, 1917	2,855	Producing.
No. 1. Staiti-Schwing	January 1917	2,683	Abandoned; entered salt.
No. 2. Staiti-Schwing			Drilling.
No. 1. Sabatier	Nov. (?), 1917	2,849	Small producer.
No. 2. Sabatier			Drilling.
No. 1. Ledet	April 16, 1917	1,707	Salt.

Sun Company.			
No. 1. Hebert	Sept. 1, 1917	3,580	Showings of oil.
Gardner-Noble, et. al.,			
No. 1. Bernard and Grima	December 9, 1917	3,200	No show.
Hineey Oil Company.			
No. 1. Grilliana		1,802	Shut down.
Paraffin Petroleum Co.			
No. 1. Sumrall		2,700	Shut down.

The operations in this district, however, have been a disappointment to date. The total production has been something like 30,000 barrels out of 19 wells drilled.

The plug of salt is of small size areally, and is marked by steep sides. (See Figures 1 and 2.) It comes to within 805 feet of the surface, and has been intruded into a series of beds in which there is a predominance of sand and gravel. The porous nature of the beds on top of and surrounding the salt, coupled with the abrupt dips on the sides, are unfavorable for a large accumulation of oil, though it is possible that in some places around the edge of the salt and possibly at greater depths some additional wells of good capacity could be made.

Houma, Louisiana.

An important gas development has occurred within the year about 15 miles southeast of Houma, in Terrebonne Parrish, Louisiana, on Section 51, T 19, S, R 18 E.

Three wells have been drilled, and each has found a large quantity of gas. No. 1, was completed March, 1917, and was drilled to a depth of 2,760 feet. It came in, making 50,000,000 feet of gas.

No. 2 was completed June, 1917, at a depth of about 2,640 feet, but the casing was perforated at 2,700-2,800 feet. It came pleted in January, 1918 (?). It was drilled to a depth of 3,585 feet, but the casing was perforated at 2,700-2,800 feet. It came in making about 2,000,000 (?) feet of gas, and much salt water.

Gas had been discovered in this locality in small quantities in shallow wells a number of years ago, the drilling having been done originally on the basis of "paraffin bed" occurrences. There

is no topographic evidence of a dome. The wells are located on flat land immediately adjacent to Bayou Terrebonne, though a small ridge is in evidence about one-half mile to the east.

The gas from well No. 2 is accompanied by a drip-condensate from the gas, of a pale yellow oil of very light gravity, the drip amounting to 5 to 10 gallons per day. This oil has the odor of turpentine. It is being used locally in Ford cars and motor boats as a fuel. It is contemplated to pipe the gas to New Orleans about 40 miles distant.

Some fossils were blown from well No. 2 from below the casing point at 2,500 feet (?). These were identified by Cooke as follows:

Fossils from McCormick Well No. 6 Lirette, Terrebonne Parish, Louisiana.

Terebra dislocata Say

Conus sp.
Cithara sp.
Cancellaria conradiana Dall
Oliva literata Lam.
Mitra lineolata Heilprin
Solenosteira mangeana Dall (var. ?)
Turritella sp.

Cooke reported these to be late Cenozoic age, probably Pliocene, but possibly Pleistocene.

The correctness of this age determination being challenged, I asked Cooke to investigate the matter further, and he reported as follows:

"In accordance with your request of June 8th, 1917, I have re-examined the shells from depth of 2,500 feet in McCormick well No. 6, Lirette, Terrebonne Parish, Louisiana. The literature and collections from the upper Tertiaries of North America are in such chaotic condition that it is generally difficult to discriminate between the Miocene, Pliocene, and Pleistocene fossils even with large collections, and it is especially difficult with small collections of imperfect material such as this. However, the fauna from this locality appears to be younger than Miocene, although I frankly admit that the evidence is inconclusive."

In a letter under date of February 26, 1918, he advised as follows:

"Regarding fossils from a well near Lirette, Terrebonne Parish, Louisiana, which you sent me last year and which I reported to be Pliocene or younger:

"I have recently received fossils from this vicinity which evidently represent the same fauna as yours but include a larger number of determinable species. The specimen in your collection which I at first took to be *Solenosteira mengeana* turns out to be a very closely related Miocene species, *S. vaughani*. These fossils show that Miocene, as well as Pliocene, is penetrated by these wells."

The drilling has thus far not disclosed the presence of any typical dome materials such as cap-rock, gypsum, anhydrite, sulphur, etc.

It may be that there is present here a very deep seated salt dome which has affected only the upper beds slightly, but it is equally likely that there may be here a true anticline which has permitted the accumulation of the gas from the deltaic deposits of Mississippi River.

St. Martins Parish, Louisiana.

Hager drilling in St. Martins Parish, about 8 miles northeast of St. Martinsville, near the northwest corner of the N. W. ¼ of S. E. ¼ of Section 28.9.7 has discovered a new dome. This well was abandoned at a depth of 1,800 (?) feet after having had some good showings of oil, and drilling into true dome materials.

A somewhat unusual find in this well was a sample of pinkish siliceous rock at a depth of 1,220 feet. Analysis showed a trace of sulphate of lime and about 35 per cent of carbonate of lime. It resembled volcanic ash, but Dr. Udden to whom a sample was submitted reported no ash present. The rock consists mostly of fine quartz grains with some zircon fragments.

Somewhat similar deposits are encountered in the outcrop of the Fayette sandstones of Texas and west Louisiana some 100 miles to the northwest, and they also occur in the Catahoula formation which outcrops about 90 miles to the north. If a part of this formation, the normal position of these beds

would be considerably deeper than found in this well, so that the evidence of uplift is unmistakable.

DAMON MOUND.

Damon Mound during the year has been the scene of much activity.

This is one of most conspicuous of the surficial mounds in the Gulf Coast region, and the sulphur outcroppings and gas showings attracted attention immediately after the discovery of Spindletop in 1901. Several wells were drilled at various points on the hill in the interval from 1901-1903, but these, while showing some oil in places and demonstrating the presence of salt and other typical dome materials, were without practical result. The details of these operations are given by Kennedy in Bulletin 212 of the U. S. Geological Survey and by Fenneman in Bulletin 282 and need not be repeated here. *a*

With the discovery of deep oil around the sides of the domes at Sour Lake and Humble in 1915, interest in the possibilities of the domes of the type of Damon Mound was revived.

The Texas Exploration Company (H. T. Staiti and others) started operations in July, 1915, and have prosecuted an active drilling campaign since that date. This company's No. 1 Wisdom on the west side of the hill (See Fig. 3) found an oil sand at 700 feet after drilling into the salt at 1,000 feet and pulling back. This well made for a short time about 1,200 barrels of 40 (?) gravity oil, but in the course of a few months went dead.

In February of last year Bryan No. 3, (See map Fig. 3) of the Texas Exploration Company came in a gas well with an estimated open flow of 10,000,000 cubic feet. The sand was apparently encountered at a depth of 1,447 feet. This well after being brought under control made gas for two months, and then went to oil,

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a. Hayes, C. W., and Kennedy, Williams, Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey, No. 212, 1903.

Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geological Survey, No. 282, 1906.

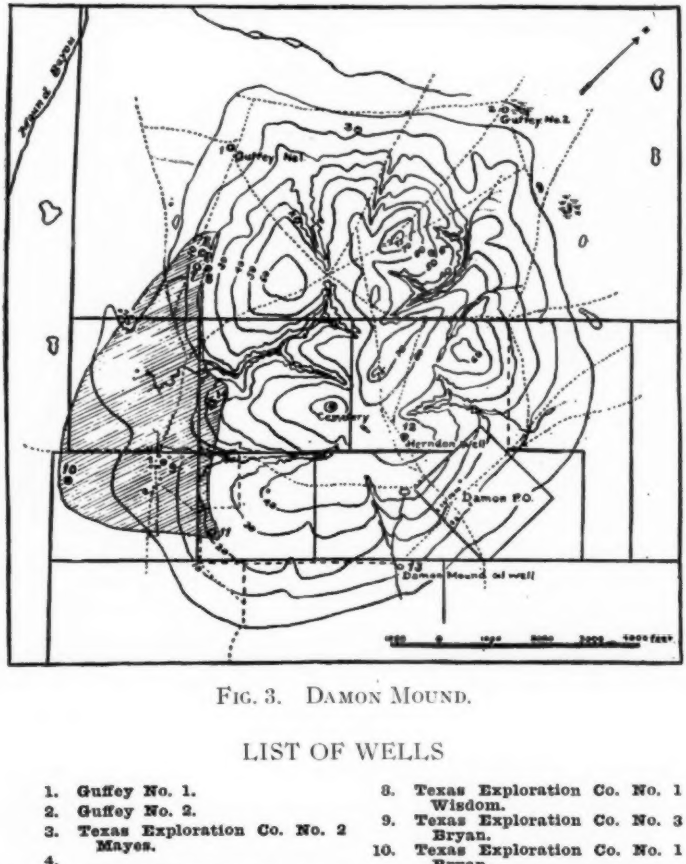


FIG. 3. DAMON MOUND.

LIST OF WELLS

1. **Guffey No. 1.**
2. **Guffey No. 2.**
3. **Texas Exploration Co. No. 2 Mayes.**
4.
5. **Texas Exploration Co. No. 1 Mayes.**
6. **Texas Exploration Co. No. 3 Wisdom.**
7. **Texas Exploration Co. No. 2 Wisdom.**
8. **Texas Exploration Co. No. 1 Wisdom.**
9. **Texas Exploration Co. No. 3 Bryan.**
10. **Texas Exploration Co. No. 1 Bryan.**
11. **Texas Exploration Co. No. 1 Becker.**
12. **Herndon.**
13. **Damon Mound Well.**
14. **Texas Exploration Co. No. 1 Masterson.**

making about 5,000 barrels. The well flowed by heads for several months and has been pumping since then.

Bryan No. 1 of this same company is located 1,740 feet southwest of Bryan No. 3. This well came in in July, 1917, at a depth of 3,474 feet, making 2,500 barrels of oil and about 3,500 barrels

of water. Apparently this well had the same sand as No. 3 Bryan, implying a dip of about 2,027 feet in 1,740 feet, or 58 degrees.

The Texas Company's No. 2 Munson about 1,700 feet northeast of Bryan No. 1 was drilled to a depth of 3,452 feet. This well penetrated a leave of salt from 2,388 to 2,701 feet and is said to have found below it some shale and sand showing oil. No production was made at this depth, and the well again went into salt at about 2,950 feet.

In the meantime the top of the hill is being actively explored for sulphur for the purpose of determining whether this mineral is present in sufficient quantity to be workable.

A list of the wells drilled at the mound to-date is as follows:

(to February, 1918).

TABLE OF WELLS AT DAMON MOUND.

Name of Well	Date of Completion	Depth	Initial production and remarks
Texas Exploration Co. No. 3. Bryan	May, 1917	1,447	5,000 bbls.
Texas Exploration Co. No. 1. Bryan	July, 1917	3,474	2,500 bbls. of oil; 6,000 fluid.
Producers Oil Co. No. 1. Munson	July, 1917	------	Small pumper; not paying.
Success Oil Co. No. 1. Bryan	July, 1917	------	Salt water.
Damon Mound Oil Co. No. 1. Mulcahy	July, 1917	------	Abandoned.
Texas Exploration Co. No. 4. Bryan	July, 1917	1,720	500 bbl. pumper.
Producers Oil Co. No. 2. Munson	July, 1917	3,452	Abandoned in salt.
Texas Exploration Co. No. 4. Wisdom	July, 1917	1,525	Salt, salt water and sulphur water.
Humble Oil & Refining Co. No. 1. Allen	August, 1917	------	Abandoned.
Humble Oil & Refining Co. No. 1. Bryan	August, 1917	1,500	500 bbls.
Producers Oil Co. No. 2. Howell	August, 1917	3,525	Abandoned.
Texas Exploration Co. No. 1. Masterson	August, 1917	1,550	Salt water.
Success Oil Co. No. 2. Anderson	August, 1917	1,700	1500 ft. of oil in hole.
Couch-Sowell Oil Co. No. 1. Fee	August, 1917	1,500	300 bbl. pumper.
Producers Oil Co. No. 1. Cove	August, 1917	------	Abandoned.

Name of Well	Date of Completion	Depth	Initial production and remarks
Success Oil Co. No. 2. Hillyer	August, 1917	------	Abandoned.
Texas Exploration Co. No. 1. Ramadohr	September, 1917	1,550	400 bbl. pumper.
Success Oil Co. No. 2. Cannon	September, 1917	------	500 bbls.
Success Oil Co. No. 3. Anderson	September, 1917	1,770	300 bbl. pumper.
Texas Exploration Co. No. 1. Woodward	September, 1917	1,700	Abandoned; salt water.
Damon Mound Petroleum Co. No. 3. Mulcahy	September, 1917	900	Dry.
Gulf Production-Texas Exploration Co. No. 1. Smith	September, 1917	2,020	Abandoned.
Texas Exploration Co. No. 1. Thomas	September, 1917	1,700	Salt water.
Humble Oil & Refining Co. No. 2. Allen	October, 1917	1,250	Sulphur water.
Texas Exploration Co. No. 4 A. Jackson	October, 1917	2,500	Abandoned.
Tarver Oil Co. No. 1. Bryan	October, 9117	2,000	Salt water.
Humble Oil & Refining Co. No. 2. Bryan	October, 1917	------	200 bbl. pumper.
Webber, Andregge and Mayes, No. 1. Lucas	October, 1917	2,000	Abandoned.
Couch-Sowell Oil Co. No. 2. Bryan	October, 1917	1,540	200 bbl. pumper.
Texas Exploration Co. No. 5. Wisdom	November, 1917	------	Abandoned.
Texas Exploration Co. No. 1. L. Z. Damon	November, 1917	1,900	Abandoned.
Texas Exploration Co. No. 3. Mrs. Damon	November, 1917	1,710	Salt water.
General Petroleum Co. No. 3. Bryan	November, 1917	1,537	200 bbl. pumper.
General Petroleum Co. No. 1. Bryan	December, 1917	1,490	250 bbl. pumper.
Texas Exploration Co. No. 5-A. Wisdom	December, 1917	690	Water well.
Swift Oil and Sulphur Co. No. 1. Freeman	December, 1917	626	Abandoned.
Texas Exploration Co. No. 3. Masterson	January, 1918	1,420	Pumper.
Atkinson Oil Co. No. 1. Bryan	January, 1918	1,600	Salt water.
Texas Exploration Co. No. 2. Becker	January, 1918	3,475	Salt water.
Success Oil Co. No. 1. Hillyer	January, 1918	2,850	Abandoned; no oil.
Webber and Andregge, No. 2. Lucas	January, 1918	1,180	Dry.
Humble Oil & Refining Co. No. 1. Gallaher	January, 1918	2,800	Dry.
Swift Oil & Sulphur Co. No. 2. Freeman	February, 1918	------	Abandoned.

It will be observed from the Map Fig. 3, that production is thus far confined to a narrow crescent-shaped area about 1,600 feet wide at the widest point and about 1½ miles long.

On the whole, however, the operations for oil have been somewhat disappointing. When the Bryan wells came in it looked like the mound would make a field, but the subsequent drilling has not been encouraging. The production at one time attained a maximum of about 6,000 barrels daily, but has now fallen to less than 1,500 barrels, certainly, a discouraging result considering the 45 or more wells, drilled to date.

However, it may be that some spots around the base of the hill, yet untested, may develop some production of good staying qualities, especially if it should be found that the dips flatten somewhat.

The test of this district has been important from several standpoints. The domes of the Coast Country may be classified as follows:

Shallow domes—cap-rock within 400 to 600 ft. below surface.

Domes of medium depth — cap-rock within 1,000 to 1,200 feet below surface.

Deep seated domes—cap-rock below 3,000 feet.

The shallow domes have the cap-rock within 500 to 600 feet of the surface, and salt within 700 to 800 feet, more or less. They are usually accompanied by pronounced surficial mounds, except where destroyed by erosion. There are steep dips on the sides. They usually have in the cap-rock small quantities of oil, but have never made commercial production from this source. Damon Mound may be taken as a type of this dome. Others include Pierce Junction, Blue Ridge, Hoskins Mound, Barbers Hill, South Dayton, Hockley, etc.

The domes of medium depth have the cap rock within 1,000 to 1,200 feet of the surface, more or less, and salt at 1,200 to

1,600 feet. The surficial mounds are not pronounced. The cap-rock contains large quantities of oil, producing originally gusher wells of large capacity. Spindletop may be taken as a type of this dome. Others include Humble, Sour Lake, Saratoga, etc.

The deep seated domes have the cap-rock below 3,000 feet, but in the known domes of this type, the cap-rock and salt have to date not been entered. Surficial mounds are absent. These produce oil from sands above the cap-rock level—evidently leakage from the main supply below. Goose Creek may be taken as a type of this dome. Others are Edgerley, Terry, and Welsh. As regards this type, some are inclined to doubt whether they are true salt domes at all, taking the view that they may be simple anticlines or faults.

Prior to the Damon development none of the shallow domes had ever been the source of large production. None of the domes in which oil had been absent in the cap-rock had made commercial production with the exception of Vinton.

After being tested in the early history of the Gulf Coast country they were abandoned as hopeless. When the deep oil was discovered on the sides of Sour Lake and Humble, as previously mentioned, interest was revived in the off-side possibilities of the shallow dome that had failed to develop production in the cap-rock. The Damon development was an experiment of this type, and thus far the experiment has not been absolutely successful, though more oil has been produced than was at one time thought possible.

It would be unsafe to conclude, however, from this experiment, that this would be true of all of the domes of this character, for while in general domes of a given type have many characteristics in common, on the other hand each is a law unto itself, and none of the other shallow type domes have been sufficiently tested to condemn them from this standpoint.

A. C. Hawkins, my assistant, has made a study of the petrologic characteristics of some of the dome materials from Damon Mound, and the result of his study shows:

The "gypsum" found in the Gulf Coast saline domes appears to be usually a very interesting combination of calcium sulphate in its anhydrous and hydrous forms. Abundant microscopic anhydrite crystals, without definite orientation or arrangement, are enclosed in a matrix of gypsum, (selenite), whose crystals have cleavage directions in parallel position throughout the specimen. In other samples the material is massive, like fine grained marble or alabaster, filled with bright anhydrites. This arrangement of the above minerals has been observed to be general in samples obtained from borings at Damon Mound, Hoskins Mound, and Pierce Junction, Texas. The anhydrite crystals are simple combinations of the three orthorhombic pinacoids, except for a few which have the form of steep pyramids. Two specimens of the "gypsum" from Damon Mound gave specific gravities of 2.37 and 2.88, respectively; the first is a specimen with pronounced cleavage in three directions; the second is very fine grained granular, with massive structure. From this determination it is seen that the first specimen contains 8.6% of anhydrite and 91.4% of gypsum, while the second has 97.2% of anhydrite and 2.8% of gypsum. Thus the cleavage of the first type is accounted for by the predominance of crystallized gypsum, which is present only in small quantity in the second, or massive, type of material.

Goose Creek

From the standpoint of production Goose Creek has been the most important development in the coast country within the year.

This district is located in San Jacinto Bay about 22 miles east south-east of Houston. (See Fig. 4.)

It was discovered originally in the summer of 1907 on the basis of gas showings and "paraffin bed" occurrences. No surficial mound is in evidence.

Up to 1916 production was secured from 1,100 to 1,500 foot sands in the heart of the present field on the Wm. Scott land

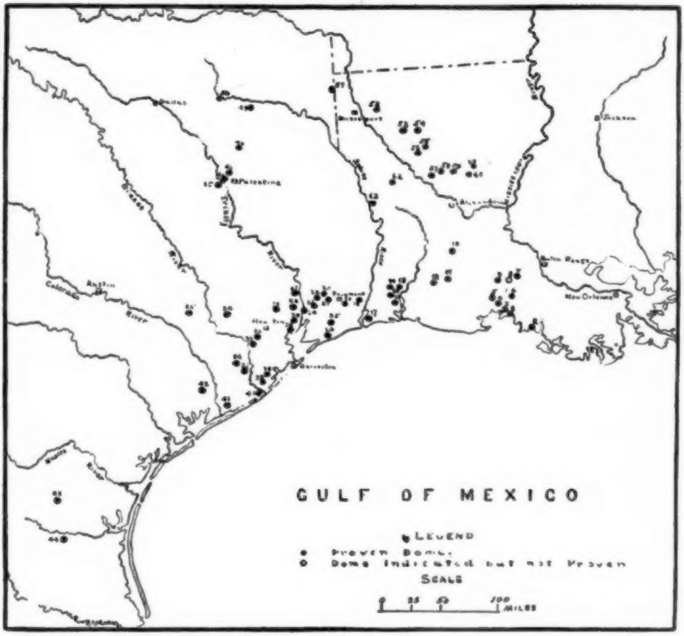


FIG. 4.

FIG. 4. MAP OF TEXAS AND LOUISIANA SHOWING COAST AND INTERIOR SALT DOMES.

1. Cote Blanche.
2. Belle Isle.
3. Week's Island
4. Avery's Island.
5. Jefferson Island.
6. New Iberia.
7. Bayou Bouillon.
8. Catahoula Lake.
9. Anse LaButte.
10. Chicot.
11. Jennings.
12. Welsh.
13. Sulphur.
14. Edgerley.
15. Vinton.
16. Hackberry.
17. Johnson's Bayou.
18. Orange.
19. Spindletop.
20. Saratoga.
21. Sour Lake.
22. Batson.
23. Big Hill (Liberty County)
24. South Dayton.
25. Big Hill (Jefferson County)
26. High Island.
27. Davis.
28. Dayton.
29. Barber's Hill.
30. Goose Creek.
31. Humble.
32. Pierce Junction.
33. Blue Ridge.
34. Hockley.
35. Brenham.
36. Damon Mound.
37. West Columbia.
38. Hoskins Mound.
39. Stratton Ridge.
40. Bryan Heights.
41. Big Hill (Matagorda County)
42. Markham.
43. Piedras Pintas.
44. Falfurrias.
45. Butler.
46. Keechi.
47. Salt Works.
48. Brooks Saline.

49. Stein's Saline.
50. Grand Saline.
51. Rambo Saline.
52. Bistineau Saline.
53. King's Saline.
54. Rayburn's Saline.
55. Price's Saline.
56. Drake's Saline.
57. Couchie.
58. Winnfield.
59. Cedar Lick.
60. Castor.
61. Brown's Saline.
62. Many.

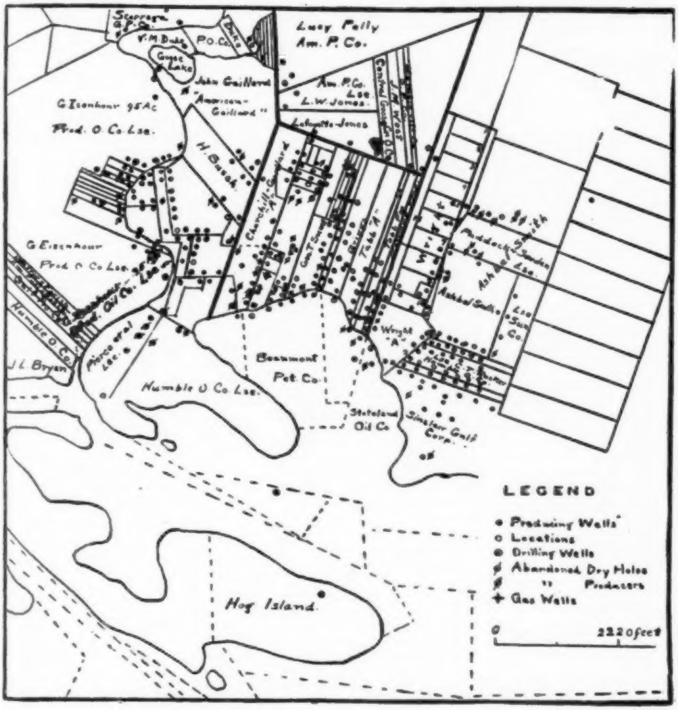


FIG. 5.

MAP OF GOOSE CREEK OIL FIELD, HARRIS COUNTY, TEXAS

(See Fig. 5) though the Texas Company had drilled a well on the Jones tract north of present production to a depth of 2,630 feet, and the Gulf Company had drilled on the Scaregga, northwest of present production, to a depth of 2,525 feet without result.

The production in this interval was as follows:

PRODUCTION AT GOOSE CREEK, 1907-1915.

Year	Barrels
1907	
1908	
1909	
1910	
1911	
1912	
1913	249,660
1914	186,578
1915	151,684

In August, 1916, Charles Mitchell and associates, drilling on the Gaillard tract, 500 feet west of production, entered a coarse sandstone at 2,001-2,017 feet, which gushed oil at the rate of 10,000 barrels per day and sanded up in a few days.

This discovery inaugurated an active period of development, still in effect, and resulted in greatly increased production. The figures 1915 to 1917 inclusive are as follows:

PRODUCTION AT GOOSE CREEK, 1915-1917, INCLUSIVE

Year	Barrels
1915	151,684
1916	599,085
1917	7,747,990

Drilling has disclosed pay sands in the heart of the old field at 1,900, 2,100, 2,500, 2,600, 3,000 and 3,300 feet, and apparently the lowest one is not yet reached.

Among the phenomenal wells completed within the year should be mentioned the Simms-Sinclair well No. 11 on the Sweet tract completed in August, 1917, at a depth of 3,027 feet, and the Gulf Production Company's Stateland No. 4 in Tabbs Bay, completed in July, 1917, at a depth of 3,072+ feet. The former came in a 35,000+ barrel gusher, sanding up, however, in a few days, and the latter came in a 12,000 barrel gusher.

Production has been extended one-half mile to the west of original production and about three-fourths of a mile to the south, but only 500 feet to the north. Apparently all of Tabbs Bay comes within the range of the proven area.

The Staiti well on the Duke came in April, 1917, at a depth of 3,556 feet, making 2,000 barrels, and extending production one-half mile to the northwest. It is still producing. The West Virginia Oil Company's well No. 2 on the Dolen came in March, 1917, making 9,000 barrels, extending gusher production one-half mile to the west.

The Allison well on Hog Island came in December, 1917, making 800 barrels, 80 per cent water, and extending production three-fourths of a mile to the south. It is 3,400+ feet deep.

Notable deep tests without result in extending production were the Magnolia Well on the Duke drilled to a depth of 4,113 feet, and the Empire Company's well on the Adey, drilled to a depth of 3,834 feet.

Of immediate geologic interest attention might be called to the following facts:

The age of the oil sand is as yet not definitely determined, as few fossils are brought up in the cuttings. Fossils secured from the Briant well on the Busch 20 acre tract in the west part of the field at a depth of 1,220 feet were *Rangia cuneata* (determined by Cooke), representing a fauna not older than Pliocene.

To date no typical cap-rock, gypsum, anhydrite, or salt has been penetrated in this structure. None of the black shales such as occur around Humble and many of the other domes have been encountered, though recently the Gulf Production Company's Well, No. 9 Stateland-Producers, encountered a somewhat similar shale at 3,580 feet, the first of the kind noted, but it is doubtful if this is identical with the shales occurring at the other domes. Any salt core present lies evidently at great depth, unless some of the untested area in Tabbs Bay should disclose the high point at a shallower depth.

The sands are unusually thick in places, and are irregularly cemented with a calcareous cement into hard rock.

In the area of production no pronounced dips are in evidence. There is only a very gentle arching of these beds extending from the south line of the Jones tract to the north end of Hog Island. There is a steep dip to the east on the eastside of the field, in evidence on the Gulf Production Company's Houston-Smith lease.

The facts seem to indicate that there is present here a very deep seated salt core, which has not been penetrated. This has arched very gently the overlying sands and clays. Slight fracturing has permitted the escape into these sands of solutions producing the irregular cementation above noted. It has also permitted the invasion of these sands by oil and gas, supplied by an oil-bearing shale in close contact with the salt, but as yet not penetrated by the drill.

MISCELLANEOUS FEATURES.

Other items of interest to which attention might be called are as follows:

Sour Lake: Large production and gusher wells have been developed from a deep sand on the north side of Sour Lake, the deep sand having been discovered originally in December, 1913. Notable among the large wells drilled in this sand in 1917 was the Gulf Production Company's No. 14 Humble-West drilled to a depth of 2,295 feet and with an initial production of 12,000 barrels.

On the south side of the dome, a black shale similar lithologically and probably also stratigraphically to the black shale at Humble, is present, and wells of light oil are made in sandy streaks in this shale. The Younts-Lee No. 2 Gilbert, completed August, 1917, made 1,500 barrels of 31.5 gravity oil from a depth of 4,240 feet, probably the deepest producing oil well in the Gulf Coast country. The test seems to demonstrate that the oil of the coast domes is coming from a deep-seated source, and it seems to confirm the opinion expressed by me before the last meeting that the black shale—apparently the source of oil at Humble and Sour Lake—is older than Miocene and probably Yegua or upper Eocene.

Saratoga: Thus far no deep oil has been found in the Saratoga district, though a few wells have been drilled on the west? south? and east? sides.

Rio Bravo, which controls most of the holdings in this area, has made a test to the northeast of present production. The well drilled into anhydrite at about 1,600 feet with no oil sand and oil shale above it.

West Columbia: The dome nature of this locality was discovered about 1901. The Equitable Mining Company's well

No. 2 was drilled about 1904. It flowed 5 barrels of green oil for about 16 months at a depth of 480 feet. Salt was drilled into in the West Columbia Well No. 1 at about 800 feet and gypsum in the Brazos No. 2 at 800 feet. Active prospecting for deep oil was resumed at this locality in October, 1913. The Texas Company has drilled within the last three years 8 or 9 holes on the north and west sides of the dome. The deepest of these was No. 2 Smith, 3,200+feet. Several of these holes have encountered the oil-soaked black shale, but very little sand was found, and no production was developed from them.

In May, 1917, The Tyndall-Wyoming Company, drilling on Lot 18 of the Hog Sub-division, on the southeast side of the dome encountered a sand at 2,830 feet. This well made on the pump for a few weeks about 25 barrels of green oil.

A few weeks ago, this company completed a second well on Lot 17 of this sub-division about 400 feet northwest of the former well. This was 2,636 feet in depth, and came in making 200 barrels of oil, but in the last few days has stopped flowing and will be put on the pump. Very lttie gas pressure seems to be present in these wells.

In some of the Texas Company's wells a heaving shale was encountered at a depth of 2,200 feet, more or less. This shale heaved out of the hole, and was difficult to penetrate. Apparently the phenomenon is due to a dry condition of the shale, the water used in drilling coming in contact with it, causing expansion, and the condition observed.

White Point: Developments at White Point on Nueces Bay in San Patricio County during the year have been disappointing from the standpoint of oil production.

This locality was originally discovered in November, 1914, when a 50,000,000 cubic foot gas well was brought in at a depth of 2,255 feet. Since then a score or more wells have been drilled for the purpose of finding oil, or making a gas well. The gas wells with two exceptions have been invariably lost because of blow-outs. The Gulf Production Company drilled its White Point No. 5 to a depth of 4,500+ feet, and abandoned the same in October, 1917. It passed through gas strata at 2,200 and 3,500 feet. No oil was encountered at a lower depth.

In the drilling thus far done, no typical salt dome formations such as cap-rock, salt, or gypsum have been encountered. If the structure is a salt dome it is evidently a very deep seated one, but it seems more likely that the structure is an anticline or structural dome.

DISCUSSION.

Mr. Thomas: What led to the discovery of the New Iberia dome?

Mr. Duessen: The New Iberia dome was discovered primarily through the interest aroused in "paraffin dirt" by a paper written by Lee Hager, but put out under the name of W. C. Moore. The title of the paper is "Indications of Oil in the Gulf Coast Country." This pamphlet was widely distributed in South Texas and South Louisiana and numerous people in these sections made a search for this earth. Among them was a gentleman by the name of Sorelle living in the vicinity of the New Iberia dome. He found the earth and also the gas showings, and after finding them, succeeded in organizing a local company to develop the property. The Gulf Company's scouts learned of the occurrence of the "paraffin," and thereupon made arrangements with the local company to operate jointly in the development.

Mr. Thomas: Is the showing of gas and "paraffine" unusual or are they sufficient to call attention thereto?

Mr. Duessen: I think if a geologist experienced in the Coast country should happen to see these indications, he would at once pick out the locality as probably marking a salt dome. However, it is not invariably true that the paraffin marks a dome, but in certain sections of the Coast country, it is almost an infallible guide. I suppose that one of the keenest persons working in the Coast country is Lee Hager. I think he has discovered more domes than almost any other person there, and he depends almost entirely upon these showings.

Mr. Perrine: In looking over the statistics of wild-cat wells drilling in the Coast country recently, I noticed that out

of something like one hundred wells, 95 per cent or more were dry. I am wondering if there is not something wrong with the system of drilling, or are these wells located without the result of geological investigation.

Mr. Deussen: Very few of the wild-cat wells in the Coast country are located upon the advice of really competent geologists. We have a great many pseudo-geologists, wiggle-stick men and others of one kind or another who locate many of these wells. Many of them are located on the basis of no sound indication. Even in the case of one of the larger companies, locations are made without respect to valid indications. Most of the larger companies, however, are guided by sound geological advice in their drilling operations.

Mr. White: In your study of Gulf Coast domes, have you come to any conclusion as to the validity of Harris's theory regarding the origin of these domes?

Mr. Deussen: It is safe to assert that the more we study the domes the less we know about them.

I think there is a sound basis for belief that the domes are associated with structural lines running northeast and southwest in Texas. As to whether there is a series of cross-folds or faults, I am somewhat in doubt. As I stated before the last meeting of this association, I am inclined somewhat to the belief that dome formation is originally initiated by volcanic action.

A RESUME OF THE PAST YEAR'S DEVELOPMENT IN KENTUCKY FROM A GEOLOGIC STANDPOINT

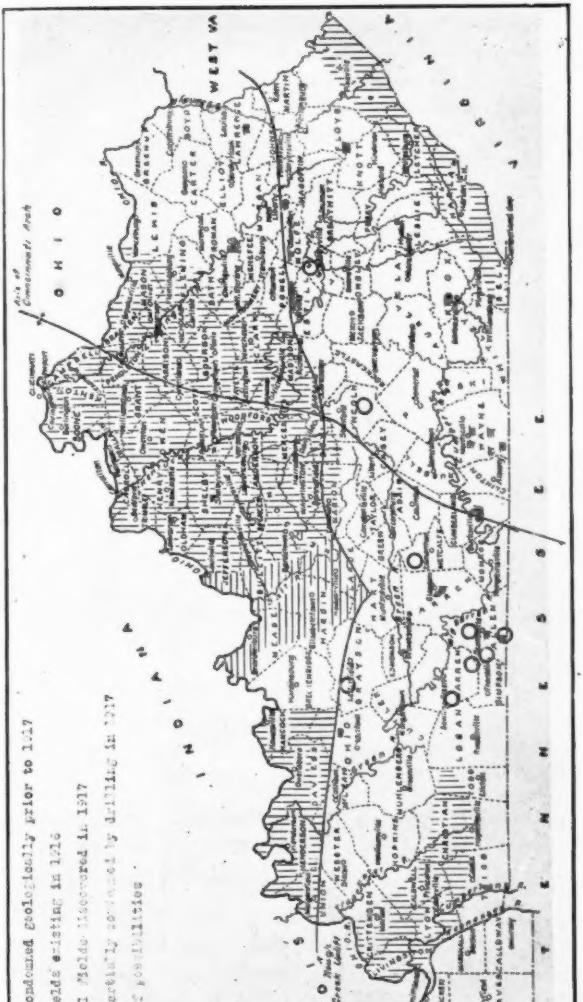
By J. R. PEMBERTON, *Lexington, Kentucky*

INTRODUCTION

At the end of 1916 there were in Kentucky many well defined oil producing fields and several gas fields. Since 1906 the total annual production of oil for Kentucky and Tennessee combined decreased from 1,213,000 barrels in 1906 to less than half a million barrels in 1915. In 1916, due to the slightly better prices then prevailing, new drilling increased the production for that year to 1,203,246 barrels. Due to the certainty of higher prices in 1917, operations in search for oil increased to a marked extent. Early in the year geologists in vast numbers entered the Blue Grass state and were followed by leasers. By the middle of the summer most of the state was under lease, geological examinations had revealed many promising structures, and wildcat drilling had commenced both on geologically approved ground and apparently worthless areas. Out of approximately 1700 wells which were drilled, 1226 were productive and the total production for the state during 1917 was conservatively estimated at 4,000,000 barrels. Inasmuch as the price per barrel at the well increased from $1.95 to $2.25 it is generally conceded that the state had a good year. The Cumberland Pipe Line, which handles the bulk of the oil is entirely inadequate for the increased new production and plans have been made for doubling its capacity. It seems highly probable that 1918 will see the production increased to 10,000,000 barrels.

OIL FIELDS AT THE END OF 1916.

The accompanying map shows the fields which were established at the end of 1916. Noteworthy features of the production are its wide geographic distribution in the state and the wide



OUTLINE MAP OF KENTUCKY.

range of geologic horizons from which it is produced. Though the greater part of the production came from the Devonian, oil was also secured in commercial quantities from the Waverly of the Mississippian, the Hudson and Niagara of the Silurian, and the Trenton in the Ordovician. The following list gives the important details of each of the old producing fields, arranged in the order of importance.

Irvine, Campton, Stillwater and Cannel City: These are situated in eastern Kentucky and lie in an east and west line along the south side of a fault. The oil is from the Devonian excepting at Cannel City where the Hudson (Silurian) is productive. The depths range from 100 to 1,500 feet in going from west to east. The controlling structure is anticlinal.

Wayne and McCreary County Fields: These are situated in southern Kentucky. The oil is from the lower Mississippian, Silurian and Ordovician rocks, and is found in synclines, due to lack of salt water, at depths ranging from 400 to 1,000 feet.

Busseyville District: It is situated in Lawrence County in the northeastern part of the state. There is small production from the Pottsville, Mississippian and Devonian at depths ranging from 700 to 2,000 feet. The structure is monoclinal.

Busseyville: It is situated in Lawrence County in the northeastern part of the state. There is small production from the Pottsville, Mississippian and Devonian at depths ranging from 700 to 2,000 feet. The structure is monoclinal.

Barbourville: It is situated in the southeastern part of the state in Knox county. The oil is found in the Pottsville and Waverly in the Mississippian at depths ranging from 160 to 1,500 feet. The structure is monoclinal.

Beaver Creek: It is located in eastern Kentucky in Floyd County. The oil is from Pottsville, and is found in synclines at depths from 500 to 1,200 feet. The production is small.

Glasgow: It is situated in the southwestern part of the state. Oil is found in the Waverly, Devonian and Niagara at depths of from 210 to 400 feet. The structure is probably a broad gentle anticline. The oldest well in the state was drilled

here in 1865 and came in at 150 barrels and still produces small quantities of oil.

Allen County Fields: These are situated in the extreme southwestern Kentucky. Oil is found in synclines and anticlines in the Devonian at depths of 80 to 200 feet.

Ohio County Fields: These are situated in western Kentucky. The oil is from a broad anticline in Silurian rocks at depths of 1,500 to 1,700 feet.

Besides these fields must be mentioned the old Burksville field in Cumberland County which long ago produced nearly all the oil then coming from Kentucky and in which the first well to produce oil in the United States was drilled in 1826. This field in 1916 was flooded with water and is non-productive. Another field not heretofore mentioned is the Menifee County gas field, lying to the northeast of the Irvine field which, however, does not produce oil.

Geological Conditions Affecting These Fields.

The important basic factors which governed the occurrence of oil in Kentcky as understood at the end of 1916 were as follows:

Structure.

With the exception of some very small fields, well defined anticlines or synclines controlled the production, notably in Irvine, Ragland, Wayne County and Allen County Fields.

Oil Horizons.

The bulk of the production was obtained at varying depths below the Devonian (Chattanooga) black carbonaceous shale. Exceptions occurred in fields where Pennsylvanian rocks are at the surface, production being then partly above the Devonian.

Areal Geology.

The bulk of the oil and nearly all of the producing wells occurred in areas underlain by the Devonian. Exceptions to this

were the Olympia, Bath County fields and the Burksville, Cumberland County fields where production was obtained in horizons below the shale but where the shale has been removed exposing the older formation.

The Irvine field, where the production is from the Corniferous porous limestones immediately below the black shale, was assumed to be the type of large producing fields and thus the Corniferous itself was manifestly given considerable merit and in wild-catting this horizon was the principal bed which was expected to produce oil. As a matter of fact the Corniferous as shown by Hoeing in the "Oil and Gas Sands of Kentucky" does not occur over more than a quarter of the entire state. Any good porous limestone within a hundred feet or so below the Devonian shale would be entirely suitable as a reservoir for oil.

Sand Conditions.

With the exception of the production from the Carboniferous rocks, which was only a small part of the total, all the oil bearing horizons were porous limestones. Naturally very spotted territory and erratic "sand" conditions would be expected. This is particularly noticeable in the Irvine field where the line between salt water and oil is very irregular and where small pools occur in isolated areas between other pools all of which are located on the same structure and have apparently the same possibilities.

Salt Water.

Due to the irregularity in porosity of the limestones the saturation of unproductive areas by salt water was known to be erratic also and in wild-catting no certainty existed as to whether salt water would be encountered in new areas and even when encountered, its upper level could not be estimated and could be ascertained only by testing.

Thus the situation confronting the hopeful wild-catter was one of uncertainty in nearly every important factor upon which his hopes were based. This, however, was offset by the geologic evidence that the Devonian Black Shale underlay all but the Blue Grass region, (the Cincinnati Arch) and a great number of scattered wild-cat wells drilled prior to 1917 had shown that all over the state there were small showings of oil below this shale. The natural assumption was then, that suitable structures might

serve as accumulation basins for large quantities of oil, although the presence of salt water to aid in the accumulation was unknown and the porosity of the rocks was entirely an open question.

Under these conditions nearly all of the larger oil companies and a great many new operators entered the state and Kentucky became easily the most active state east of the Mississippi.

New Pools Discovered in Eastern Kentucky.

Drilling was carried on in nearly every county in the state and the following is a list of the points at which really new pools were discovered as evidenced by new producing wells. The broader features concerning these new discoveries are given as they are known at present. Naturally there is much to be learned yet regarding many of the details of each of these pools and especially their limits, due to the fact, that in none of these new pools has any definite outline been established.

Estill County: More drilling was carried on in Estill County than in any other, and out of 753 wells drilled, 142 were dry. Most of this drilling was supposedly inside the limits of the established field and was successful. The dry holes serve to show the spotted character of the sands. However, the field was extended in several directions, notably to the south and east and the exact limits are perhaps not sharply set at present. With the exception of this conventional extension, nothing new of importance was developed.

Powell County: The most prolific single lease in Kentucky is no doubt the famous Ashley lease belonging to White Brothers. This lease is located well outside the supposed limits of the Estill-Powell County fields to the southeast of the main field. At the end of 1916 oil had been struck there, but during 1917 drilling was carried on rapidly, and by the end of the year there were some 45 wells, each producing from 20 to 300 barrels of oil per day. It is reported that only one dry hole was drilled. The largest well came in at about 700 barrels. Adjoining leases, such as the Rogers and Pruitt-Miller tract on the south, also proved to be enriched and the probabilities are that a large field will be developed here separated from the true Irvine field by an unproductive belt.

The oil comes from two horizons rather close together, both in the Devonian limestones below the Black shale. The depth ranges from 740 to 850. The fact that the drilling is so shallow makes it certain that this part of the county will be thoroughly tested.

While the broad Irvine anticline controls the accumulation of oil in this district, there is no separate dome or anticline in this new pool. The location is well down on the flanks of the main fold and near the head of a local syncline trending east and west. Local "sand" conditions probably of a more porous nature than in the rocks to the north and east are responsible for the accumulation. The production cuts off on both east and west apparently, and on what is exactly similar structures. From these facts it is entirely problematical where other pools may lie and no reasons can be advanced to show why oil may not occur in large quantities in other places along the flanks of the Irvine anticlinal structure.

Lee County: Several notable wells were brought in some seven or eight miles southeast of the Ashley district in Powell County in the so-called Poplar Sign Board and Fincastle district in Lee County. Considerable drilling resulted in the discovery of probably three or perhaps four separate and distinct pools, all in new territory, and very likely Lee County will take its place as an oil producer.

The wells are in three distinct groups. At the Poplar Sign Board there are two new wells rated at from 10 to 40 barrels. The oil bearing horizon is the Devonian limestone lying below the Black Shale and thus in this particular, the wells resemble those of the Irvine fields. The depth is about 1,200 feet due, to the elevation of the ground at this place. No remarkable structure presents itself and the accumulation is no doubt controlled by local sand conditions, combined with slight terraces, on the monoclinal structure of the region. The surface beds are the lower Pennsylvanian, dipping gently toward the east and southeast. Besides the two wells near the Sign Board, several others in the same locality have shown that there are possibilities in the whole district.

Near Beattyville, six miles further south, another strike was made, the wells making between 25 and 40 barrels. The depth is between 1,100 and 1,260 feet, the elevation being much lower than at the Sign Board, though also considerably lower structur-

ally. The occurrence of the oil is the same as in the wells at the Sign Board or in the Devonian limestone.

Between Beattyville and the Sign Board, near Fincastle, other strikes were made under the same conditions.

Wild-catting became extremely active in this part of Lee County and 58 wells were drilled, although the greater number of them were dry. Due to the peculiar occurrence of the oil it appears that many more dry holes will be drilled before the pools will be well defined, but nevertheless, considerable production is bound to result in Lee County.

Knox County: In the Barbourville and Cumberland River districts of Knox county, the old well established pools there led to considerable new drilling. About 50 new holes were drilled and two distinct new strikes were made with five 50 barrel wells actually producing. These strikes were made at about 400 feet depth in the Pottsville (Pennsylvanian) sandstones.

The structure seems to consist of minor terraces of small extent on the general southeast monocline of the region. This field has been drilled thoroughly it seems and it is doubtful if any other good new pools will ever be opened up.

Wayne and McCreary County Fields: The well defined pools in this district were not extended excepting in a very limited degree and no real new strikes were reported. Wild-cat drilling was also very limited, only 60 wells being reported as completed and 30 of these were dry. There seems to be little likelihood of important extension of existing pools or new strikes in this region.

New Pools in Western Kentucky.

It was in western Kentucky that the most progressive and far advanced wild-catting occurred. Practically every county was tested to some extent and in at least three counties, Grayson, Warren and Allen, strikes of such a nature were made that there is now no doubt but that the present year will see the development of important oil fields here. Already pipe lines and refineries are being planned to care for this new and isolated production.

Grayson County: The broad, well defined anticline which extends in an east and west direction right across Grayson County and directly beneath the town of Leitchfield, seems to be assured of oil, according to the results already obtained. Tests have been made on top of this fold, both on its eastern end and well toward the west, also well down on both the north and south flanks. The results of six wells drilled in the county so far, show that gas in large quantities may be obtained from the crest in the east, but that salt water is present on the flanks in the limestones of the Devonian beneath the black shale. In only one well was oil obtained on the eastern portion of the structure from the Devonian, but this was shortly replaced by salt water. The eastern portion of the anticline is the higher, as the fold plunges toward the west.

In the western portion of Grayson County, about 8 miles west of Leitchfield, both gas and oil have been obtained in paying quantities. Only one well so far has actually produced large quantities of oil, but with the coming of spring drilling will no doubt be carried on until a prolific pool is developed. The oil comes from an unexpected horizon high up in the Mississippian and undoubtedly several hundred feet above the black shale. The depth is 530 feet and beginning with about 60 barrels per day, the well settled to 5 barrels after several weeks. Gas was encountered in another well in another part of the county, at 900 feet in about the same horizon. The nearest production to this prior to 1917 was in Ohio County to the west, also on the same general structure. This production however, comes from well below the black shale and very likely production may be obtained from this lower level in Grayson County also.

The oil is exceedingly high grade, gravity running about 40 Baume, and this fact, coupled with the shallow depth at which it is obtained, and the fair production, insures complete development.

Warren County: About 35 miles south of the Grayson County strike, wild-cat drilling resulted in the bringing in of at least 5 good producers, out of 15 wild-cat holes, scattered over about a township area. There is a well defined anticline running in a general east and west direction and plunging toward

the west, upon which the new production occurs. The depth runs about 1,200 feet or slightly less, in one well the oil occurs at 1,112 feet. The production comes from Niagara limestones about 120 feet below the black Devonian shale, the Corniferous probably being absent here. The wells flowed in several instances and are all from 30 to 50 barrel producers, the oil being of the highest grade, over 40 degrees Baume, and entirely lacking in sulphur which is present in notable quantities in much of the western oil.

The bulk of the leases in the probably productive territory is held by three or four large companies and proper development of the county seems assured.

Allen County: Oil has been known to occur for the last 60 years in Allen County, several small wells, apparently being capable of producing all this time. Drilling, in years previous to 1917, had resulted in drawing attention to this county and 1917 saw very active operations.

There have been in 1917 notable extensions of the four existing pools, the North Petroleum, Rodimer, Wildwood and Hinton and new drilling has uncovered at least six new pools. These are well separated and lead to the belief that others may be encountered.

These new pools are located as follows: The Big Trammel Creek area is in the western part of the county joining Warren County, and is located on the same general structure that controls the production in Warren County. This pool is 7 miles west of Scottsville, the Wheat farm being the lucky one. The well was drilled in and considered dry, but afterwards began flowing and is now a well of 40 barrels. The Gainesville pool on the Moore farm, about 8 miles north of Scottsville, is the second new strike, a well here 300 feet in depth flowed oil in varying quantities, estimated all the way from 100 to 700 barrels, but which after filling all available storage, was shut in and has not been allowed to settle. It is at least a good producing well. The little hamlet of Adolphus in southern Allen County, close to the Tennessee line, has been the scene of several new wells producing from 5 to 50 barrels. The depth ranges from 80 to 200 feet and town lots are being utilized as drilling sites.

Just across the Allen County line in Warren County, near the hamlet of Alvaton, is another new strike. This came about through a well being drilled to a depth of 550 feet and after being abandoned, was found later to contain oil, filling the hole about 300 feet. It was then pumped and produces at least 10 barrels. Another strike was made just across the Allen County line in Simpson County, close to the Warren County line. This well is only 85 feet deep and came in a 60 barrel well, but declined afterwards to 10 barrels.

All of these new strikes are located on small flat domes and plunging anticlines and the oil is all from Niagara limestones at varying depths below the Devonian black shale. The oil is all high grade, about 40 Baume, and is shipped in tank cars to Nashville, Tennessee. The whole Allen County field produces from 500 to 1,000 barrels per day.

Next to the immediate vicinity of the larger fields in eastern Kentucky, Allen County has been the most active county in Kentucky during 1917. Because of the extremely shallow drilling required, wild-catting was easy and not expensive as small rigs could be used. Over 150 wells were drilled, of which about 70 were dry. Ordinary water well rigs with a donkey engine and vertical boiler are sufficient to test the Niagara formation. Some operators however, are considering drilling deep wells to test the Trenton at depths of from 800 to 1,500 feet. This formation has produced all the oil in Cumberland County, two counties removed to the east, and no reason can be advanced as to why production should not be secured from the Trenton. Several of the wells were caused to flow by gas pressure which declined rapidly in an hour or so, but newspaper comment gave out information to the effect that 1000 barrel wells were a daily occurrence in Allen County.

NEW STRIKES IN SOUTHERN-CENTRAL KENTUCKY

Considerable wild-cat drilling resulted in new and important development in Lincoln, Green and Metcalfe Counties. In Lincoln County a good field is assured, in Green County a small gas field has been located and in Metcalfe County the small strikes made there, are of sufficient importance to warrant the

assumption that a field may be developed there, comparable to the Allen County pools.

Green County: A plunging anticline, with a slight terrace but no definite closure, has developed gas in notable quantities in six wells. The depth ranges from 210 to 340 feet and the gas is obtained from either the lower portion of the Devonian (Corniferous) or the upper Niagara limestones and from 23 to 32 feet below the Devonian black shale. Salt water was not present in the gas horizon but was encountered in one or two other dry holes in strata well below the gas sand. This, together with the results of many other dry holes seems to indicate that oil will not be found lower structurally than the gas, and probably a fair gas field sufficient to supply the needs of a small town could be developed. Arrangements are already being made to supply gas to several of the county seats near by.

Out of seven completions no showings of oil, of note, have been found in this region.

Metcalfe County: Drilling in the northern part of this county has resulted in the bringing in of two small wells near Sulphur Wells. These wells are on the flanks of a fault and obtain the oil at shallow depths and from strata below the Devonian shale, and produce together about 20 barrels of oil per day. Nine holes in all were drilled. To the south and in the same county are several important structures which are as yet untested, but owing to the results to the north and to the production in Allen and Warren (Glasgow) fields, expectations are that a producing field will be developed in this county.

Lincoln County: The first out and out wild-cat strikes of the year were in Lincoln County and several small producers at shallow depths were brought in, out of a total of 30 wild-cat holes. This new pool is located south of the hamlet of Otterheim, a little south of the center of the county. Eight producing wells in all have been brought in, the initial production being about 20 barrels per day in the best well and the settled production being five barrels. The depth is about 250 feet and the oil occurs in porus limestone, probably of Devonian age, below the Devonian black shale. The writer has not visited the field and the structural features are unknown. Since this

pool became well established one lease with two producing wells was reported sold for $35,000.00 and $100,000.00 was offered for a block of leases with two wells but the offer was refused. The oil is reported as being of high gravity and of good refining quality.

Unsuccessful New Drilling.

Central Northern Kentucky: Within the area over which the Silurian and Ordovician rocks are exposed, comprising the region of the Cincinnati uplift, nine holes were drilled in widely separated localities, and with the exception of some minor quantities of gas, no success resulted. This is an area already condemned by geologists and the drilling substantiates their claims. At the same time, much in favor of drilling could be said of some spots, where well closed domes occur and the possibilities of the Trenton rocks were unknown over most of the area. However, several of the most promising of the structures have been drilled to depths sufficient to test all possible underlying oil bearing horizons, with no results.

Eastern Kentucky: The western flanks of the Cumberland Plateau, comprising the eastern coal field and covered by the Pennsylvanian rocks, were the scene of much testing. Over one hundred holes were drilled, some on apparently favorable structure, while others were drilled according to the "lay of the land." With the exception of small showings, some gas, enticing looking oil sands a few very small producers, mostly in Lawrence County, this region did not live up to expectations. Salt water, sulphurous gas and absolutely dry holes were obtained in most instances. However, this portion of Kentucky is far from thoroughly tested and many fine structures are awaiting the drill. The most favorable localities are along the south side of the Irvine fault which traverses the state and probably is to be considered as running into the Chestnut Ridge Fault of West Virginia.

In Southeastern Kentucky the counties of Floyd, Knott, Perry, Clay, Leslie and Laurel have not by any means been condemned and favorable structures may develop productive fields.

Central Southern Kentucky: In this portion of the state drilling has met with but little success. The greater part of this area is covered by the Mississippian rocks with some Pennsylvanian farthest to the east and southeast. Drilling is shallow and 75 holes were drilled. Gas and salt water were found in some localities, but as a whole the salt water does not seem to be as constant in its occurrence as it should. Apparently this is spotted territory if productive at all. Lincoln County, already treated, is the only portion of this part of the state, in which any favorable results have been obtained, with the exception of the gas field in Green County. This region lies along the axis of the Cincinnati arch, which connects with the central uplift in Tennessee, and probably this structurally more elevated portion of the state will not be found to be enriched as much as on the flanks.

Western Kentucky: In Meade, Hardin, LaRue and Hart Counties, where considerable drilling has been done, nothing but salt water and small amounts of gas has been secured. Apparently good porous limestones beneath the shale which would contain oil farther to the south, as in Allen and Warren Counties, are here barren of all oil. It is true that some gas has been found, but it is usually native gas in the black shale, which being so carbonaceous and carrying so high a content of oil, 12 to 15 gallons per ton according to U. S. Geol. Survey experiments, should be expected to furnish small blows of gas when punctured. Apparently these four counties will never become oil producers.

Other western counties have practically not been touched with the drill, only about 15 wells having been sunk outside of counties in which strikes were made, and many areas in the western coal fields may become prolific. Considerable drilling is being planned for 1918 and possibly some of the well defined structures will be proved to be enriched.

SUMMARY.

1. Wild-cat drilling in 1917 resulted in the discovery of many new and distinctly valuable oil pools, some of them far from previous production.

2. In western Kentucky anticlinal structure controlled all of the new pools and geologists were responsible for the locations.

3. In eastern Kentucky local sand conditions seem to play a more important part than local structure, although new pools were located on the flanks of the larger anticlines.

4. In western Kentucky several good closed structures were found flooded with salt water below the Devonian black shale and were barren of oil.

5. As a general rule, all new testing is carried to a distance of at least 200 feet below the Devonian black shale.

6. Many untested structures remain and other areas in favorably located territory, and 1918 will undoubtedly see much wild-cat drilling and probably new pools will be encountered.

7. With the exception of the Grayson County strike, which demonstrates the presence of a new oil bearing horizon high up in the Mississippian, nothing new regarding the occurrence of oil in the state has been discovered and the essential geological conditions, as understood for Kentucky, governing exploration for oil, have not been changed.

NEW DEVELOPMENT FOR OIL AND GAS IN OKLAHOMA DURING THE PAST YEAR AND ITS GEOLOGICAL SIGNIFICANCE.

By Geo. E. Burton, *Norman, Oklahoma*

General Statement.

Development Showing Oil or Gas in or Closely Associated With the Base of the Permian.

General Statement.
Garber.
Billings.
Cement.
Yukon.
Woodward.
Origin of the Oil and Gas.
Economic Importance.

Development Showing Oil or Gas in or Closely Associated With the Top of the Missisippian.

General Statement.
Origin of the Oil and Gas.
Economic Importance.

Summary.

General Statement.

The new development during the past year can be classified under two general heads: First, that development which found production in or closely associated with the base of the Permian; and, second, that development which found production in or closely associated with the top of the Mississippian.

So far, we have generally supposed that the original source of the oil and gas in Oklahoma has been the Pennsylvanian strata. The fact that oil and gas have been found in western Oklahoma at a depth somewhat shallower than the supposed thickness of the Permian in that area and in the north-central part of the State much deeper than the supposed thickness of the Pennsylvanian, has forced us to explain how the oil and gas migrated from the original source, or change our figures concerning the thickness of the Permian and Pennsylvanian in these areas, or modify our general statement concerning the origin of oil and gas.

Development Showing Oil and Gas in or Closely Associated With the Base of the Permian.

General Statement.

In connection with this topic the following areas are especially interesting: Alva, Woodward, Yukon, Cement, Billings, and Garber.

Garber.

The shallow production in the Garber field is found at a depth of about 900 feet. The surface contact between the Permian and Pennsylvanian as mapped by Beede* lies about 35 miles east of the Garber field. The general west dip of the Permian strata has been considered to be about 35 feet per mile. The base of the Permian would, therefore, be expected at an approxi-

*Beede, J. W., Oklahoma Geological Survey Bulletin No. 21.

mate depth of 1,250 feet in the Garber field. Thus, this shallow production appears to be about 350 feet above the Pennsylvanian-Permian contact. There is, then, the possibility that this gas is within the Permian sediments.

Billings.

The shallow production in the Billings field is found at a depth of about 500 feet. This field is about 30 miles west of the outcrop of the Pennsylvanian-Permian contact, and considering this west dip of the Permian strata to be about 35 feet per mile, this contact would lie at a depth of about 1,050 feet and the gas probably 550 feet above the base of the Permian.

Cement.

The record of the Emily Kunsemuller well No. 1, sec. 32, T. 6 N., R. 9 W., shows an oil sand at a depth of 500 feet, a gas sand at 745 feet, and a large flow of gas at a depth of 1,440 feet. It is hard to figure the probable depth of the Permian in this area. The log of the well mentioned above shows alternations of sandstones and shales which are "done" in the following colors: red, gray, white, blue, brown, and variations of these. In the upper 500 feet of this well there is a predominance of red and for that reason it has been classified as Redbeds—a rather useless classification as far as our purpose is concerned. The Redbeds do not occupy a definite stratigraphical horizon. They do not extend to the base of the Permian in the north-central part of the State nor are they confined to the Permian, the Pennsylvanian strata in the east-central part of the State having the same color as the adjoining Permian to the west.

It is hard to say whether the oil and gas found in the upper part of the above mentioned well is from the Permian or from the strata which underlie it. In this connection it is interesting to note that the log of the Fortuna Oil and Gas Company's well in the southeast corner of sec. 31, T. 6 N., R. 9 W., reports no red rocks at all. The first showing of gas in this well was at a depth of 930 feet. Other strikes of petroleum in this well were as follows: at 1,180 feet, showing of oil; at 1,615 feet, showing

of oil; at 1,665 feet, showing of oil; at 1,725 feet, showing of oil; 1,918 feet, showing of oil; at 2,040 feet, showing of oil; at 2,080 feet, oil and gas; at 2,130 feet, oil and gas; at 2,340 feet, oil; at 2,221 feet, oil and gas; at 2,340 feet, gas whose volume was 30,000,000 cubic feet.

It is the opinion of Buttram* that this well started in the Pennsylvanian and that all the production in this well is from the Pennsylvanian strata.

YUKON.

The Yukon Co-operative Oil Company reported a strike of gas at a depth of 1,834 feet. It is hard to estimate the thickness of the Permian in this area. The record of a well drilled at El Reno shows the Redbeds to extend to a depth of 1,800 feet. The Yukon well is about 10 miles east of the El Reno well and if the 35 feet to the mile west dip holds good for this area we would expect this gas in the Yukon well to be about 300 feet below the base of the Redbeds. But the Redbeds and the Permian are not identical, and there is a probability that the gas in the Yukon well is from the Permian.

WOODWARD.

A few months ago a good deal of excitement was caused by the reported strike of oil at a depth of 1,550 feet in the Red Hill Oil Company's well in sec. 23, T. 23 N., R. 20 W. This well reported gas at a depth of 914 feet. Shortly after the reported strike of oil in the above well, the Home Producers Oil Company reported a strike of oil in their well in sec. 3, T. 21 N.,. R. 21 W.

There has been a good deal of discussion concerning this reported strike which was found where the estimated thickness of the Permian is 2,500 to 4,000 feet. The well first reporting the strike of oil has been guarded as a mystery well and little definite information can be obtained concerning it. Some doubt is expressed by a good many geologists and oil men as to whether the well had a legitimate strike of oil. There are others, however, who think that the strike was legitimate. In either case,

*Buttram, Frank, Geologist, Fortuna Oil & Gas Company.

our attention is called to the possibilities and the necessity for more detailed information concerning underground conditions in the Permian area.

ALVA.

In connection with reported oil discoveries near Woodward the progress of Cosden Oil and Gas Company's well drilled on the Whitehorse anticline in sec. 8, T. 22 N., R. 16 W., is interesting. The latest report on this well (Jan. 9, 1918) shows that it has reached a depth of 3,900 feet without a showing of either oil or gas.

ORIGIN OF OIL AND GAS.

I accept the organic theory for the origin of petroleum as the true explanation. I would not, therefore, expect to find oil and gas indigenous to the Permian. This paper contains no positive proof that oil and gas have been found in the Permian, but oil and gas have been found within the area of the outcrop of the Permian so much shallower than expected that an attempted explanation of this fact may be of interest. To my mind either or a combination of the following, explains the shallow production in the Permian area: (1) The Pennsylvanian is much nearer the surface in the Permian area than we have supposed; and (2), the Permian sediments are possibly of such a nature as to permit oil and gas to migrate directly upward.

In the former case our explanation for the occurence of oil is the same as it is for the occurence of oil in any of the fields producing oil from the Pennsylvanian strata. There is no reason why the Pennsylvanian might not be near the surface, not in general, but in specific areas. There may be up-folds in the Pennsylvanian which are not apparent at the surface.

I am not sure of the second case and suggest it only as a possibility that warrants experimentation. We do know that the Permian shales contain considerable sand, also that the horizontal variation in both sandstones and shales is very marked. It may be, that the pressure of ground water could force oil and gas upward in these formations. This, of course, would explain the presence of oil and gas within the Permian sediments.

ECONOMIC IMPORTANCE.

Whatever the explanation for the shallow production in the area of the Permian outcrop the fact that oil and gas have been found at shallow depths is of vast economic importance. It opens up a vast area for exploration and just now the method of exploration is the important consideration. Most geologists are agreed that the determination of structure from surface outcrops in most of the Permian area is, to say the least, unsatisfactory. Even the determination of structure from surface outcrops, uncertain as it is, does not take care of vast areas where there are no outcrops. In this connection I wish to call attention to Circular No. 8 of the Oklahoma Geological Survey. This circular recommends that in areas of unreliable outcrops or in areas of no outcrops the diamond drill be used in exploring for structure before a location for a deep test is made.

DEVELOPMENT SHOWING OIL AND GAS IN OR CLOSELY ASSOCIATED WITH THE MISSISSIPPIAN.

GENERAL STATEMENT.

From time to time reports come in saying that oil and gas have been found in the Mississippian below the Pennsylvanian. Within the past year such reports have come from the Osage, from Muskogee, and the Glenn Pool.

ORIGIN OF THE OIL AND GAS.

It is entirely consistent with the organic theory of the origin of petroleum to say that this oil and gas is within the Mississippian strata. In other states large quantities of oil and gas have been produced from the Mississippian. Any oil found within the Mississippian at some depth is probably indigenous to it. It is possible, however, to have oil and gas, which originally was present in the Pennsylvanian, accumulate in the upper porous strata of the Mississippian. For instance, irregular areas of Chattanooga shale occupying depressions at the unconformable contact between the Pennsylvanian and Mississippian might furnish a supply of petroleum which might accumulate in adjacent areas of Mississippian strata which project up into the Pennsylvanian. Production of this sort would be very irregular. These

irregularities in the position of the contact between the Pennsylvanian and Mississippian may be erosional irregularities or may be irregularities caused by folding and faulting.

Economic Importance.

The finding of oil and gas within the Mississippian is of economic importance because it increases the territory within the State worthy of exploration. It is interesting to note in this connection that the intensive drilling explorations in the Miami district for lead and zinc have not encountered oil or gas in paying quantities.

Summary.

The new production in Oklahoma during the past year may be classified as follows; that which found production in or closely associated with the base of the Permian and that which found production in or closely associated with the top of the Mississippian. No data have been submitted which proves that oil and gas have been found within the Permian. Oil and gas have, however, been found so much shallower than expected that we are forced to explain this shallow production either by supposing the Pennsylvanian to be much nearer the surface than we have previousely supposed or that the nature of the Permian sediments is such as to permit the passage of oil and gas and water upward from the Pennsylvanian. Likewise, no data have been submitted which proves that oil and gas have been found within the Mississippan strata at great depths below the Pennsylvanian. Oil and gas are, no doubt, produced from Mississippian strata in contact with the Pennsylvanian, but probably originally came from carbonaceous Pennsylvanian shales which occupy depressions in the Mississippian.

Norman, Oklahoma, January 25, 1918.

THE OIL AND GAS FIELDS OF NORTHERN LOUISIANA.

By Mowry Bates, *Tulsa, Oklahoma.*

All of the oil and practically all of the gas produced in Northern Louisiana are found in Caddo, Bossier, Red River and DeSoto Parishes, which comprise the northwestern corner of the State. Both oil and gas are also obtained just across the line in Marion County, Texas. An additional small gas producing area has recently been discovered in Ouachita and Morehouse Parishes, Louisiana. The oil producing territory lies in an elongated oval about 65 miles long and 25 miles wide, beginning in T. 22 N., R. 15 W. and extends slightly east of south to T. 12 N., R. 10 W. The eastern side of Marion County is included in the oval. There are three main producing oil fields and two gas fields in this district. They are known as the Caddo field, which includes Ferry Lake, Mooringsport, Oil City, Monterey and Pine Island, and all production in the vicinity; the Naborton or DeSoto field; and the Red River-Crichton field in which was found the famous Gusher Bend.

The main producing gas fields are the Shreveport and Monroe. The Shreveport field includes the producing districts of Cross Lake, Curtis, and Elm Grove. The Elm Grove district also produces a small amount of oil from the Chalk Rock. The Cross Lake district lies northwest of Shreveport and the Elm Grove southeast of Shreveport. The Monroe field is located 115 miles east of Shreveport. The Caddo oil field, with the exception of the Monterey district, produced a large amount of gas. The Vivian anticline on the east edge of the Caddo field was especially productive.

General Geologic Features.

The general geology of Northern Louisiana, Northeastern Texas and Southern Arkansas has been excellently described by A. C. Veatch in Prof. Paper 46, U. S. Geol. Survey, entitled "The Underground Waters of Northern Louisiana and Southern Arkansas." The earlier work in the Caddo field has been recorded by G. D. Harris in Bulletin 429, U. S. Geol. Survey,

"Oil and Gas in Louisiana," which also describes many features of the saline domes of Southern Louisiana.

George C. Matson has written an especially complete report on the Caddo field up to 1915 in Bulletin 619, U. S. Geol. Survey, "The Caddo' Oil & Gas Field, Louisiana and Texas. Bulletin 661-C, U. S. Geol. Survey—"The DeSoto Red River Oil & Gas Field," by George C. Matson and Oliver B. Hopkins, is a very exhaustive study of the southern portion of the Sabine uplift.

The general surface features of Northern Louisiana consist of low rolling sandy hills of Eocene and Quartenary sediments. The principal drainage course is the Red River, which runs from the northwest corner of the State about south 15 degrees east.

Low reliefs (not to exceed 100 feet at any place) and the unconsolidated character of the surface formations practically prohibit any detailed geologic study of structural features except from well logs. Fortunately the rotary logs are generally well kept with fairly accurate pipe measurements, and the Nacotoch Sand (Gas Rock) is an excellent key, as the contact with the Arkadelphia clay above is very sharp and well defined. A general section taken from Bulletin 661-C, U. S. Geol. Survey, is given.

GENERALIZED SECTION OF THE FORMATIONS SUPPOSED TO UNDERLIE THE SABINE UPLIFT IN NORTHERN LOUISIANA AND EAST TEXAS. BULL. 661-C, U. S. GEOL. SURVEY.

SYSTEM	SERIES	THICKNESS	GROUP	FORMATION
Quarternary	Recent			
	Pleistocene	0-200		
Tertiary	Eocene	300-900 200-300		Wilcox formation Midway formation
		300-600 100-160 150-750		Arkadelphia clay Nacatoch sand Marlbrook marl
	Gulf (Upper Cretaceous)	Plus 100 150-500	Austin	Annona chalk Brownstown marl
Cretaceous		400-700		Eagle Ford shale (including Blossom sand member) Woodbine sand
		0-400	Washita	Denison formation Fort Worth limestone Preston formation
	Comanche (Lower Cretaceous)	25-30	Fredericksburg	Goodland limestone
		500-600		Trinity sand

The Wilcox is the only formation found in the highland portion of the Sabine uplift outlined on the accompanying key section. The bottom lands are covered with river sand and clay.

General Structural Features.

The Sabine uplift, the principal structural feature of the district, brings the Nacotoch sand as high as 700 feet below sea level, giving a total upward movement of more than 1,000 feet. Only the higher portion where crossed by secondary folding, which has a general axis of N. 80 degrees E., is productive. The oil and gas pools noted above are on these secondary folds, while there is a non-productive one at Blanchard, some 12 miles north of Shreveport.

Several smaller domes are found on the flanks of the main uplift as in northeastern Shelby County, Texas, and the Pelican district in T. 10 N., R. 12 W., on the north line of Sabine Parish.

Occurrence of the Oil and Gas.

The only productive horizons are in the Cretaceous. The Nacatoch Sand (Gas Rock) produces gas in all the different fields and some heavy oil east of Oil City. Occasionally a well is found in the Anona chalk which in places is porous. The Blossom Sand contains a great deal of gas, with an occasional showing of oil. The so-called Woodbine Sand produces practically all of the oil in Northern Louisiana. There is some question as to the age of this main producing oil sand in as much as the fossils found in the wells during the past three years indicate that it may be Eagle Ford rather than Woodbine. A sand some 200 feet below the present production often gives large volumes of gas and is probably the real Woodbine.

In the Caddo field the average interval from the top of the Nacotoch to the Blossom is 1,000 feet and to the producing sands 1,325 feet. These intervals vary somewhat in different wells. In the Naborton field the interval from the Nacotoch to the producing sand is 1,625 feet and in Red River it is 1,660 to 1,700 feet, an increase of some 350 feet over the northern part of the uplift. This difference is distributed quite evenly and one can estimate sufficiently close for casing points by allowing a divergence of five feet per mile from Mooringsport to Crichton.

Production.

The total production of Northern Louisiana from 1906 to 1913 inclusive was 30,628,243 barrels, all from the Caddo field. In 1914 the Naborton field, in T. 12 N., R. 12 W., was discovered and during the year produced 3,834,593 barrels. The west side of the Red River-Crichton field was opened late in 1914 and produced 401,622 barrels. Caddo produced 7,572,254, making the total production for 1914, 11,808,469 barrels. In 1915 the Naborton production dropped 2,000,000 barrels to 1,797,175 barrels. The Caddo district decreased over a million barrels, producing 6,471,879 barrels, but the Red River-Critchon production jumped over six million barrels, the field producing 6,802,349 barrels. The Pelican district produced 10,631 barrels, making the total for the year 15,082,034 barrels.

In 1916 Caddo lost another million barrels, Naborton 100,000 and Red River-Crichton two million, the total production being 11,821,641 barrels, a net loss of 3,260,392 barrels or 21.62%.

In 1917 Caddo produced 5,736,185 barrels, an increase of some 400,000 barrels above 1916. This increase is largely due to the Ferry Lake lease of the Gulf Refining Company of Louisiana, which is a remarkably productive property.

Naborton, Red River-Crichton and Pelican produced 2,911,840 barrels, which is 3,446,120 barrels or 54.2% less than in 1916.

The total production of Northern Louisiana from 1906 to 1917 inclusive has been 77,988,413 barrels.

The Caddo Field.

The general features of the Caddo field have been so thoroughly and excellently discussed by Mr. Geo. C. Matson in Bulletin 619, U. S. Geol. Survey, that the writer feels some hesitancy in commenting on the field at all.

The general structure runs northeast and southwest with cross folding at almost right angles. On this structure are a number of minor domes which yield the production. If Mr. Matson had contoured the Nacatoch sand with ten-feet intervals these minor domes would have shown more clearly. There is undoubtedly some faulting but it is hard to map owing to discrepancies in logs.

The principal production is in the so-called Woodbine Sand, with the exception of some heavy oil found in the Nacatoch in T. 22 N., R. 15 W. The only new discovery for two years in the Caddo field was in what is known as the Pine Island district, which is located in T. 21 N., R. 15 W. The discovery well was drilled in sec. 28 by the Producer's Oil Company and made 10,000 barrels. This well was drilled in early in December and together with the steady development of the Ferry Lake lease of the Gulf Refining Company in T. 20 N., R. 16. W., accounts for the small gain in the production of the Caddo field. No other large wells have been found and the escaping gas in the Producers well caused the smaller wells to stop flowing. The strike has caused some delay in both new and old work.

The Caddo field is surrounded by dry holes to the west in Texas. The structure to the north drops off into a deep syncline, and to the east the gradual dip throws the sands below the water level. The syncline to the south between the Caddo and Blanchard structures is peppered with dry holes. The future of the Caddo field depends entirely on inside drilling and the discovery of minor domes, such as the Producers found in 28-21-15. There have been many instances of this character in the history of the field.

Naborton Field.

The Naborton field is located in the northeast corner of T. 12 N., R. 12 W., the southeast corner of T. 13 N., R. 12 W., and along the south line of T. 12 N., R 11 W. The production is found on top and on the north flank of a long fold or anticline extending from Naborton to east of Crichton. In the vicinity of Naborton several small domes are found which produced wells as large as 3,000 barrels natural. The most recent development is the small production in sec. 34, T. 13 N., R. 12 W., where the Producers Oil Company opened a small pool in the fall of 1915 and the spring of 1916. Since that time there has been no development of interest. The territory in all directions has been drilled with negative results. It is possible to predict, with a fair degree of certainty, favorable locations in Louisiana, as all production is on structure which can be mapped from well logs and the probable structure projected. There have been sufficient wells

drilled around the Naborton district to define the main structure, both to the north and south. The water limit is clearly defined. All the oil is found on the minor domes and on the north flank, as the sand conditions do not seem to be favorable for the accumulation of oil on the southern flank of the fold. In fact, the south central part of T. 12 N., R. 11 W., had very little sand at the producing horizon, but produced some gas in the deeper sand. The structure was favorable but the sand conditions were poor. A few small wells were found during the past year on the east side of T. 12, R. 11, but the production is small. The year's development consisted in drilling inside wells and drilling up large acreage. Nothing new has been discovered.

Red River-Crichton Field.

The Red River-Crichton lies to the northeast and along the axis of the same fold as the Naborton pool and some 120 feet lower on the structure. There is also an increase of some 40 feet in the interval between the Nacatoch sand and the producing sand. It was supposed at first that the Crichton production was a lower sand but a careful study of the section proves the sand the same, as correlation can be carried from one field to the other.

The principal production is found on four domes in T. 13 N., R. 10 W., and R. 11 W. The production is cut off to the south by a fault extending from sec. 2, T. 12 N., R. 11 W., to near the northwest corner of sec. 21, T. 13 N., R. 10 W. This fault has a total throw of 220 feet to the south and cuts off abruptly the enormous production of Gusher Bend. It worked out so exactly that one could predict wells or dry holes 200 feet apart. It might be of interest to know that the faulting was evidently subsequent to the beginning of the accumulation of the gas, as gas was trapped and sealed by water in the sands on the down throw side; as soon as the pressure was lowered the water came in.

The height of all development in this field was in 1915. 1916 saw the beginning of the decline and 1917 produced nothing new. The first well in the field was drilled by the Gulf Refining Company on the Marston lease in sec. 14, T. 13 N. , R. 11 W. This opened the Marston-Kennedy pool, which produced wells as large as 1,200 barrels. In the fall of 1915 Wolfe & Keen drilled

Weiss No. 1 in sec. 18-13-10, which came in making 6,500 barrels. In the fall of 1915 the famous Gusher Bend was opened.

The wells decline rapidly and are expensive to operate, as individual pumping is required. The production follows the structure very closely and a difference of 10 feet means oil or water on the north slope of the anticline.

The field has been surrounded by dry holes, so nothing new can be expected.

Shreveport and Elm Grove Gas District.

The principal gas production is found in the Nacatoch sand, or, as it is locally called, the Gas Rock. All the gas is on structure and follows it closely.

The oldest development is in Shreveport and just to the west and north. This pool has produced gas for many years, both for local consumption and use in Arkansas, where it is piped by the Arkansas Natural Gas Company. The structure has two directions of folding and forms an almost perfect cross with the highest point just west of Shreveport. Several deep tests have been made with negative results. An occasional new well is drilled. The pressure is low and few produce more than 1,500,000 feet. Some of the deep wells produced gas in the lower sands but not enough to drill for.

Some five miles south and east of Shreveport and west of Curtis a very prolific gas field was opened in the fall of 1915, the first well being Youree No. 3, drilled by the Gulf Refining Company, which came in at 42,000,000 feet per day. This was followed by many others, though during the past year drilling has been slow. This gas is from a stray or higher sand than the regular oil sand, but it is below the Blossom. No oil has been found in any of the wells.

The Elm Grove dome was opened in early 1916 and has produced a large number of gas wells in all four sands, the Nacatoch, the Blossom and the so-called Woodbine, and in a sand 300 feet below. Elm Grove also has several small wells in the Chalk Rock which came in as high as 100 barrels. No oil has been found in the deeper sands. The Elm Grove field is on a large dome, which has a rise of some 120 feet. The gas follows the structure absolutely. It was discovered simultaneously by Mr. John Y. Snyder of Shreveport and the writer, who

also located the Curtis field. The Arkansas Natural Gas Company has tried to extend this field to the east but without results. It is surrounded by dry holes.

There is a dome near Blanchard in T. 19 N., R. 15 W., between Shreveport and Mooringsport. This dome has been thoroughly tested and proven dry by a number of deep wells.

The Monroe Gas Field.

The Monroe gas field is located some 115 miles east of Shreveport and from 6 to 18 miles north of Monroe. It has come into more or less prominence during 1917. A small gas well was drilled north of Monroe some four years past. Wells as large as 40,000,000 cubic feet per day have been developed. The field is about 10 miles long. The gas is dry and no oil has been found as yet. The gas is found just above the chalk at about 2,200 feet, in what may be the Nacatoch sand. The structure is reported as being large and very flat. No secondary folding is known as yet but more drilling will probably develop minor domes. A well now drilling in sec. 13, T. 20 N., R. 3 E., in Union Parish is said to be on or near the highest part of the structure and should tell the story as to oil.

The district to the east has been drilled with no results as yet.

Scattered Wildcats.

Northern Louisiana is the home of the wildcatter. Land is generally owned in large blocks and water and fuel are always plentiful. It is almost impossible to do any surface geology, hence the geologist cannot safely condemn any specified location unless one has an immense number of logs and elevations to work with. At the best only a surmise can be made.

On the eastern and southern sides of the Sabine uplift a number of Saline domes are found. Some of these are too high, that is, the Cretaceous has protruded through the Eocene and has been eroded. Others are mere indications, such as salt and sulphur springs, with an occasional outcrop showing the steeply dipping structure. A number of these have been drilled with negative results. It is possible, however, that at any time a productive Saline may be found. All uneroded domes should be tested.

A dome in the Black Lake district, T. 11 N., R. 6 W., has had several gas showings but no oil as yet. In Western Sabine Parish, near Logansport, a number of wells have been drilled without results. In Shelby County, Texas, southwest of Logansport, one small well has been found. In Panola County, northwest of Logansport, several small wells were found during the past two years. Neither of these discoveries have as yet amounted to much, as the wells are deep and the production small.

A well near Plain Dealing, in Northern Bossier Parish, caused some excitement and considerable drilling, but it soon went into water and all the balance have been dry holes.

Wells are now being drilled in Grant and Rapides Parishes. Several dry holes have already been drilled in this general area, so little can be hoped for from these wells. Two small wells were opened up at Lake End in T. 11 N., R. 9 W., in the south end of Red River Parish. The production is small as yet.

Conclusions.

It would appear from a careful study of Northern Louisiana and East Texas that the history of petroleum in this area has been written. Unless the Monroe dome should develop oil the industry resolves itself into a problem of inside drilling and careful efficient operating. The wells are costly to drill and operate. The oil is not of the best grade and Northern Louisiana is not an attractive proposition at present.

GEOLOGICAL CONDITIONS IN CENTRAL KANSAS.

By IRVING PERRINE, *Hutchinson, Kansas.*

INTRODUCTION.

A brief study of a map of Kansas showing the oil and gas development to date reveals clearly the limited extent of the oil and gas fields as yet discovered by the drill. With few, almost no exceptions, all producing oil wells will be found south and east of a line drawn from Kansas City southwest to Ottawa, then south-southwest to Leroy, then west through Dunaway to Burns, then southwest to Potwin, and from there almost straight south to the Oklahoma line. Even within this area there remains a vast amount of untested acreage, destined to add enormously to the State's production in the future. North and west of this line stretches a field for geologic research whose possibilities for oil and gas development only the future can foretell.

For the past year the writer has maintained geological headquarters at Hutchinson, Kansas, spending a major portion of his time in the study of geological conditions in South Central Kansas. Inasmuch as an increasingly large number of tests have been and are being made in this region, a brief review of the general geology of Central Kansas, with notes on the structural conditions, might be of some assistance to others working in the same field.

PRINCIPAL GEOLOGICAL WORKERS IN CENTRAL KANSAS AND RESUME OF THE MORE IMPORTANT PUBLICATIONS.

Professor Haworth, in his well-known "Oil and Gas in Kansas", vol. IX of the State Survey publications, divides the geological investigations made in Eastern Kansas into three groups chronologically arranged: first, from the earliest investigations down to about 1875; second, from this date to the organization of the University Geological Survey of Kansas in 1894; and third, from 1894 to the present time.

During the first period the principal workers in Central Kansas were Messrs. Meek, Hayden, Hawn, Swallow and Cope. Meek and Hayden published mostly in the Reports of the U. S. Geological Survey; Hawn in the Missouri and Kansas State Survey Reports and in the Transactions of the St. Louis Academy of Sciences; Swallow, in the Kansas State Survey Reports for 1866 and in numerous scientific journals; Cope, mainly in the Reports of the U. S. Geological Survey.

Messrs. Mudge, St. John, Robert Hay and Williston are those whose names stand out prominently in the second period. Most of their publications will be found in various reports of the Kansas scientific publications.

Among the many workers in the field since 1894 must be mentioned the names of Prosser, G. I. Adams, Beede, John Bennett, Logan, Case, Haworth, Gould, Kirk, Cragin, Hay, Knowlton, Darton, Williston, and Sellards.

The more important papers dealing with the geology of Central Kansas may be found in the Reports of the U. S. Geological Survey, especially Prof. Paper No. 32, Bulletin No. 613, Folio No. 109, and the 16th and 22nd Annual Reports; Reports of the University Geological Survey of Kansas; Reports of the Kansas State Board of Agriculture; Transactions of the Kansas Academy of Science, and the Kansas University Quarterly.

Physiography*.

The area considered in this report may be regarded as being bounded on the east by the Flint Hills upland, which extends north and south across the State, the cities of Salina, Newton, Wichita and Arkansas City lying just west of the upland proper.

Five physiographic divisions, as defined by Adams, make up the central portion of Kansas: the Great Bend prairie extending east from Dodge City along the Arkansas River to the Oklahoma line; the Smoky Hills upland, occupying the region north of this to the Nebraska line; the Oklahoma prairie, occupying the position of the outcrop of the Red Beds below the first gypsum beds; the Red Hills upland, to the west of the Oklahoma prairie, and separated from it by the Gypsum Hills escarpment; and the High Plains, to the west and north of the Red Hills upland.

*Footnote—Taken largely from G. I. Adams' "Physiographic Divisions of Kansas", Trans. Kans. Acad. Sci., vol. XVIII, p. 109.

In that portion of its valley known as the Great Bend, the Arkansas River has carved out the soft Permian shales and the basal, more easily eroded shaly beds of the Dakota (using this term in the broad sense), reducing the country to a flat, lowland condition. This lowland is locally composed largely of sand, in places forming well defined sand dunes. These dunes range in height from 10 to 40 feet or more, those on the north side of the Arkansas River being probably formed of sand blown from the river bed, many of the others being derived from Tertiary sands exposed in areas farther west, partly weathered and blown eastward. The Great Bend prairie merges with the structural plain on the western slope of the Flint Hills to the east and with the rolling plains of the Oklahoma prairie to the southwest. The Equus beds, to be discussed later, belong in this physiographic province.

The Smoky Hills upland is formed of Cretaceous rocks, the dividing line between this province and the High Plains being the Blue Hills escarpment formed by the Fort Hays limestone of the Niobrara. Topographically, the Smoky Hills upland consists of rather indistinct terraces, with isolated buttes and mounds. A number of streams cross the upland in nearly parallel eastward courses, giving a rather uniform series of broken slopes and steep river bluffs with intervening terraces.

The Oklahoma prairies may be characterized briefly as rolling plains, crossed by streams with low, gently sloping divides. Geologically, the province is coextensive with the outcrop of the Enid formation of Oklahoma.

Separated from the Oklahoma Prairies by the Gypsum Hills Escarpment (the Blaine Gypsum of Oklahoma), rear the white bordered walls of the Red Hills dissected upland, its flat-topped hills and buttressed escarpments forming, when seen from a distance, "a landscape of striking beauty, which, once seen, will never be forgotten. The reddish color of the steep sides of the hills, whose walls suggest gigantic fortifications, is clearly visible, while the tops of the hills appear in the hazy distance like a great table-land."*

Grading without perceptible difference of elevation, but rather by a series of steps within the Red Hills themselves, the

*Footnote—(Prosser, Univ. of Kans. Geol. Surv., vol. II, p. 85.)

uplands merge into the broad High Plains, which cover the whole of Western Kansas and stretch out to the foot-hills of the Rockies. Formed by the spreading of a mantle of Tertiary sediments over the older rocks, the whole presents the appearance of a monotonous dead-level plain, broken, however, by fantastic erosional forms, where the streams have cut deep troughs into the underlying Cretaceous rocks. Held up by their sod, the plateau surfaces suffer practically no degradation save the narrowing of their frontal margin by sapping of the small streams at the foot of the bluffs.

STRATIGRAPHY.

General Statement.

In Central Kansas rock exposures representing the Permian, Comanchean, Cretaceous, Tertiary and Quaternary periods may be found. The rocks are exclusively sedimentary, shales, sandstones and unconsolidated sands and gravels predominating, limestones being comparatively unimportant, except in the areas underlain by the Cretaceous. For convenience, the discussion of stratigraphy will be divided into two parts, the surface formations, and those encountered only in drilling.

Columnar Section.

Quaternary
- Alluvium
- Sand hills
- Equus beds

Tertiary
- Mortar beds, sands, gravels, Tertiary "grit," etc.

Cretaceous
- Pierre shale
- Niobrara formation
- Benton group
- Dakota sandstone

Comanchean
- Lower part of Dakota sandstone (so-called) locally
- Mentor beds
- Kiowa shales
- Cheyenne sandstone

- Permian
  - Cimarron series (Red Beds) — Oklahoma equivalents
    - Kiger stage
      - Taloga formation ------Quartermaster formation
        Greer formation
      - Day Creek dolomite
      - Red Bluff formation
    - Salt Fork stage ------------Woodward formation
      - Dog Creek formation
        - Chapman dolomite
        - Amphitheatre dolomite
      - Cave Creek formation---Blaine formation
        - Shimer gypsum
        - Jenkins clay
        - Medicine Lodge gypsum
      - Glass Mountain formation:
        - Flower-pot shales
        - Cedar Hills sandstone
      - Kingfisher formation: ---Enid formation
        - Salt Plain member
        - Harper sandstone
  - Big Blue series
    - Sumner stage
      - Wellington shales
      - Marion formation
    - Chase stage
      - Winfield limestone
        to
        Wreford limestone
    - "J" stage of Prosser
      - Garrison formation
      - Cottonwood limestone
    - "I" stage of Prosser
      - Eskridge shales
      - Neva limestone
      - Elmdale formation
- Pennsylvanian
  - Limestones, shales and sandstones

SURFACE FORMATIONS.

PERMIAN.

Marion Formation: The oldest formation outcropping in Central Kansas is the Marion formation of Prosser. More recently this formation has been divided into five members, the Abilene conglomerate at the top, the Pearl shales, the Herington limestone, the Enterprise shales, and the Luta limestone, which last appears locally some 7 to 10 feet above the Winfield limestone.

The Marion is the highest formation of the Kansas Permian in which fossils have yet been found, according to Prosser, and paleontologically the upper limit of the formation may be considered as defined by the disappearance of fossils. Only two species of brachiopods have been found, Derbya multistriata M. & H. and Seminula argentia Shepard (subtilita Hall), and they are confined to the lower part of the formation. The majority of the species to be found are rather small pelecypods characteristic of the Permian.

Two, possibly three, gypsum beds belong to this horizon, the Solomon and Greeley gypsum beds of Dickinson County being placed here. The interval between the three well marked gypsum horizons in Central Kansas is 140 feet, 100 feet of which marks the interval between the lower (Solomon) and middle (Greeley?) deposits.

The porous rocks in the upper part of the Marion formation have been shown by other writers to contain the thick beds of rock salt of Southern and Central Kansas. Haworth says: "Well records have been obtained from many different parts of the salt region which, when drawn to scale and compared, show very conclusively that the salt beds lie above the heavy limestone beds, and below a bed of blue shale (Wellington shales) which in turn is below the Red Beds."

Outcrops of the Marion formation are abundant in eastern Saline, and in western Dickinson, Morris, Marion and Harvey Counties. From a few miles west of Newton, the western boundary of the formation swings south and follows roughly the direction of the Arkansas River into Oklahoma. The line of division between the Marion and Wellington formations has never been accurately traced in Southern Kansas, owing to the

gradual transition in the lithological character of the rocks, the level nature of the country and the scarcity of fossils.

Owing to the difficulties of fixing the upper limits of the formation, not only in well sections, but even in the field, its thickness has never been actually measured. Various estimates range from 300 to 400 feet. In the Anthony well, 404 feet have been referred to the "salt beds."

Wellington Shales: Gray, red, green and blue shales and clays, with interbedded salt, gypsum and dolomite beds, make up the Wellington formation, as defined by Cragin. They were first named the "gray shales" by Robert Hay, in contradistinction to the "red shales" of the overlying Red Beds. The formation may perhaps be identified most readily through its negative rather than its positive characters, namely, the absence of fossils and the general absence of limestones.

In thickness the Wellington shales range from approximately 200 feet in Saline County to more than 400 feet in Southern Kansas, 445 feet being reported in the Caldwell well section, and 395 feet in the Anthony well, according to Prof. Cragin's interpretation of the well records.

As stated above, the boundary between the Wellington and Marion formations has never been sharply defined. The change from the blue and gray shales of the Wellington to the red sandstones and shales of the Cimarron series, on the other hand, is comparatively rapid, and in many places a sharp line of division may be located. The relations of the Wellington shales to the overlying Red Beds have not been carefully studied, but apparently there is a gradual change southward to beds of reddish color and of a more sandy nature. Beede attributes these changes to the direct result of the influence of the Arbuckle Mountain region upon the sedimentation of the time. Subaerial conditions continued near the mountains and marine conditions beyond the influence of its fans.

Cimarron Series—the Red Beds: For the purpose of this paper a description of the Red Beds as a group is considered sufficient, the more so since the subdivisional names as given by Cragin for Kansas, Gould for Oklahoma, and Cummins for Texas present in themselves a formidable and imposing subject for discussion.

Cragin thus concisely defines and describes the Cimarron series: "With the Wellington formation ends the Big Blue, lower, or limestone-bearing series of the Permian. Succeeding it without break, but possibly with a gradually introduced angular unconformity are the Harper sandstones and higher prevailingly red formations that comprise the remainder of the Kansas Permian and constitute the Cimarron series, which, for Kansas, is nearly the same as the 'red beds.'

So far as known, the series is destitute of any trace of organic remains."

Beginning at the Oklahoma state line, just west of the city of Caldwell, the contact line between the Wellington shales and the Red Beds can be traced in a general northwest direction through, or very close to the towns of Argonia, Norwich, Murdock, and Pretty Prairie.

Just east of Arlington a few miles, the Red Beds are buried underneath the Tertiary, Arlington representing practically the northernmost outcrop. The base of the Red Beds rests conformably on the Wellington formation, so far as present observations have revealed. The top of the series is determined on the west and north by either the base of the Comanchean or the Tertiary where the former is absent.

In Kansas, as in Oklahoma and Texas, massive gypsum beds occur in ledges of 30 feet or more in thickness and cover large areas, but the gypsums are relatively unimportant when considered as a part of the Red Beds as a whole. Their stratigraphic position is shown in the columnar section above given. A study of well records shows also the presence of two or more beds of rock salt in the Red Beds of considerable thickness and lateral extent, one in the Harper, another just below the Cave Creek gypsum beds. The Gate well record above mentioned shows over 100 feet of salt in each of these zones. Owing to the recurrence of salt beds at varying horizons from the upper Marion beds to the gypsum beds of the Cimarron series, their use as horizon markers should be attended with extreme care, especially in the study of the usually poorly kept well records of southwestern Kansas. In this connection, it might be well to state a few of the better known horizon markers of the Permian:

(1) The Neva limestone, which has been traced by Beede across the Kansas line into Oklahoma;

(2) The Wreford limestone, and its southward extension into the Payne sandstone of Oklahoma;

(3) The top of the Hutchinson salt beds, the principal salt horizon of central Kansas;

(4) The base of the Red Beds, apparently a fairly dependable horizon marker in central Kansas, where the conditions of sedimentation were comparatively uniform at the close of Wellington times, but practically valueless in Oklahoma, where its stratigraphic position is ever changing (from the top of the Wellington shales to the lower portion of the Coffeyville formation);

(5) The Shimer and Medicine Lodge gypsums;*

(6) The Whitehorse sandstone and its equivalents in Kansas (the Red Bluff standstone) and Texas (the Blowout Mountain sandstone ???).

The top of the Red Beds cannot be used as a horizon marker, inasmuch as it is everywhere in unconformity with the overlying Cretaceous or Tertiary beds.

Kansas writers have variously estimated the thickness of the Red Beds at from 900 to 1431 feet, the latter figures being quoted by Prosser as most certainly "the maximum thickness of the Red Beds in Southern Kansas."

Later well borings show these latter figures to be too small, as records at Ashland and Mineola would indicate the thickness to be at least 1535 and 1540 feet in those wells. A deep well at Gate, Oklahoma, approximately 15 miles south and slightly west of Englewood, passed through 1700 feet of Red Beds, the drill passing through 25 feet of Tertiary sediments and then into the Woodward formation. According to Gould, the overlying Greer and Quartermaster formations have a combined thickness of at least 450 feet, hence the total thickness of the Kansas Permian may reach 2000 feet, and possibly more.

*Dr. Snider, in Bulletin No. 11 of the Oklahoma Geological Survey publications, says: "The evidence is so strongly in favor of the presence of three ledges (of gypsum) throughout Woods County, and on the opposite side of the Cimarron, however, that the writer is compelled to believe, (1) either that the Ferguson is present, or (2) that a new ledge has appeared in its place or between the Medicine Lodge and the Shimer."

COMANCHEAN.

Cheyenne Sandstone: Resting unconformably on the Red Beds in parts of Barber, Pratt, Kiowa and Comanche Counties is a rather coarse-grained, friable sandstone, varying in color from yellowish gray to white, but frequently spotted and striped with bright colors such as purple, crimson, brown, etc., and named by Prof. Cragin the Cheyenne sandstone. The fossil flora of this formation places it in the Comanchean, either in the Washita division of Hill, or perhaps in the Fredericksburg below.

In thickness it ranges from 40 to 65 feet.

Kiowa Shales: "The inferiorly dark-colored and superiorly light-colored shales that outcrop in several of the counties of southwestern Kansas, resting upon the Cheyenne sandstone in their eastern and upon the 'Red Beds' in their middle and western exposures, and being overlaid by brown sandstone of Middle Cretaceous age, or Tertiary or Pleistocene deposits according to their locality," are designated the Kiowa or Neocomian shales by Cragin, and the Belvidere shales by Hill. They outcrop in a very irregular line from the northeastern part of Barber County through Comanche and Clark Counties into the eastern part of Meade County. In McPherson, Ellsworth and Saline Counties occur a number of isolated localities where Kiowa shales have been found, one especially good exposure being a few miles west of Lindsborg. In all, some 78 species have been identified from the Kiowa shales, the well known Gryphaea corrugata var. tucumcarii Marcou of the Tucumcari beds of New Mexico and West Texas, among others.

In thickness the beds range up to 150 feet as a maximum.

The Mentor Beds: On all the older geological maps the Dakota sandstone is mapped as the basal formation of the Cretaceous. Recent studies in Colorado have shown conclusively that the lower part of the Dakota is Comanchean in age, as revealed by the finding of marine Comanchean fossils. Compared with the deposits of the same age in Texas, these Colorado beds are very thin. They consist of about 200 feet of shales and sandstones, and are known as the Purgatoire formation.

Similar variegated marine shales with intercalated beds of very dark brown sandstone, resting in part conformably on the Kiowa shales and in part unconformably on the gray and purple-red shales of the Permian, and overlain by the more heavily arenaceous freshwater sediments of the Dakota, have been described from central Kansas by Professor Cragin under the name of Mentor beds. The typical exposure of these beds may be found on the east side of the Smoky Hill River about three miles east of Mentor, a station on the Union Pacific.

The Mentor beds outcrop in Saline, McPherson, Ellsworth, Lincoln, Ottawa and Clay Counties. The fauna shows a close relation to the Denison beds of Texas, and the Caddo, Bokchito and Bennington formations of Oklahoma, a number of species being common to the three areas.

In thickness these beds range from 0 to 70 or 80 feet, there being some localities where the Dakota proper appears to rest directly upon the Permian, both the Mentor and Kiowa formations being absent.

CRETACEOUS.

Dakota Sandstone: "The rocks of this group rest either conformably on the Comanche Cretaceous or unconformably on the Permian or Carboniferous. The line of demarkation between the Comanche and the Dakota has not been sharply drawn; and, in the light of our present knowledge, such a line is impracticable. The Dakota grades upward into the Benton wherever the latter is present; otherwise the upper limit is marked by a line of unconformity below Cenozoic rocks. The stratigraphy of the group has not been well understood. Instead of consisting almost exclusively of sandstone, it is found that the greater part of the entire thickness is composed of clays and shales. There is no general continuity of strata, the various members appearing and disappearing without seeming regularity. The origin of the rock is probably estuarine or beach deposits under changing conditions of elevation."*

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*The above is an abbreviated description of the Dakota as given by Dr. Gould in Vol. XVII of the Trans. Kans. Acad. Sci., pp. 122-178.

Included in the Dakota group, usually considered as a sandstone formation, are thick beds of fire and brick clays, saliferous and gypsum shales, and one or two beds of lignite which have been mined and used for fuel in Republic, Mitchell, Lincoln, Russell and Ellsworth Counties.

The line of outcrop of the Dakota group crosses the state in a general northeast-southwest direction, from Washington County on the northern boundary to Ford County, with isolated remnants in Clark, Kiowa and other counties in the southwestern part of the state.

The thickness of the group will average approximately 250 feet.

Benton Group: The uppermost beds of the Dakoto group gradually grade from sandstone into shales or from bituminous to argillaceous shales; the dividing line between the Dakota and the succeeding Benton group being placed where these lithological changes take place.

Stratigraphically, Logan has divided the Benton group into two subdivisions. The lower subdivision is made up of five principal horizons, namely: (1) Bituminous shale, 20 to 40 feet; (2) Lincoln marble, maximum 15 feet; (3) Flagstone, maximum 10 feet; (4) Inoceramus, 4 to 5 feet; (5) Fence-Post, 9 inches. In the upper subdivision are two horizons: (1) Ostrea shales, 100 to 150 feet; (2) Blue Hills shales, 100 feet. These names in themselves are briefly descriptive of the Benton group.

In its geographical extent the Benton is the largest of the Cretaceous groups. It stretches across the state from Republic County on the north to Ford County on the southwest, with isolated areas still farther west.

Niobrara and Pierre Subdivisions: The upper beds of the Cretaceous group occur north and west of the region discussed in this paper, and will not be reviewed here.

Tertiary.

The Tertiary material in Kansas is composed of gravel, sand, black sand, clay, silt, and a small amount of material usually called "volcanic ash." In Central Kansas, the Tertiary deposits consist almost entirely of brownish compact sands with occasional gravel beds. Where cemented, the gravels are locally called "grit." The harder ledges often stand out very prominently,

forming the "mortar beds" of Kansas geologists. Near McPherson is a thin bed of "volcanic ash," the easternmost deposit of its kind in the state known to the writer. Paleonthological evidence goes to show that a portion of the so-called "Tertiary beds" of Kansas may be Pleistocene. In other words it would seem rational to believe that these deposits represent the accumulations of a period of time ranging from mid-Tertiary to the present.

Probably nowhere in central Kansas will the Tertiary beds exceed 200 feet in thickness. Darton mentions 200 feet as a maximum in Pratt County.

QUATERNARY.

Equus Beds: The McPherson Equus beds cover a large area in McPherson, Marion, Harvey and Reno Counties. They occupy a large channel carved out of the Permian shales and Dakota sandstone and consist of alternating layers of sand and clay, with a heavy stratum of gravel near the bottom of the deepest part of the channel. Topographically they represent a monotonously level surface in marked contrast to the rough surface of the surrounding Permian, Dakota and Sandhill areas. The geology of the Equus beds is discussed by Prof. Beede in the University of Kansas Geological Survey, Volume No. II, but, as he states, their problem is still awaiting a satisfactory solution.

In thickness, the Equus beds range from 0 to more than 150 feet in the deeper portions of the channel.

Sandhills and River Alluvium: The Arkansas river and other large streams of central Kansas are now flowing in broad valleys whose channels are being mostly aggraded. Ample evidence is at hand to show that the Arkansas valley, at least, was formerly from 50 to 100 feet deeper than it now is, and that at the present time a filling-in process is in operation. Broad stretches of alluvium effectively conceal the geological structure of large portions of central Kansas, especially along the course of the Arkansas river. Back from this river, sometimes on one bank, again on both, there extend at varying intervals long rows of sand dunes which add further to the perplexities of the structural worker in such parts of the state. Here a compilation and careful study of the records of the numerous water and would-be oil wells of the region may enable the geologist to locate struc-

tures which might otherwise remain forever untested, unless some more fortunate wild-catter should chance to locate upon such hidden folds and bring to light new oil fields of the fast diminishnig hit-or-miss type.

SUB-SURFACE FORMATIONS.

Marion Formation: If, as we have every reason to believe. the Hutchinson salt beds belong stratigraphically in the upper part of the Marion, this formation may easily be shown to extend as far south and west as Ashland and Mineola, Kansas, and Alva and Gate, Oklahoma, and as far north and west as Wilson and Great Bend, Kansas, in all of which places the Hutchinson salt zone can readily be identified in the well records.

A log of the Hutchinson (Ben Blanchard) Prospect Well, drilled in 1887, shows 146 feet of alluvium, 104 feet of Red Beds, 232 feet of Wellington shales, 328 feet of salt and shales interbedded, followed by a series of shales, gypsums, sandstones and limestones to a depth of 1307 feet. Inasmuch as this well is located approximately fifty miles west of the outcrop of the Winfield limestone, and well records of points between are not of sufficient number or accuracy to be of assistance in determining the westward dip of the Winfield limestone, it is exceedingly difficult to determine the position of this formation in the Hutchinson well log. Correlating the first limestone encountered in the latter well with that found in the Wichita "City Well," and allowing for differences of elevation, the limestone at Wichita is roughly 180 feet the higher. This would be equivalent to a dip of 3.6 feet per mile to the northwest from Wichita to Hutchinson, should these limestones prove to be synchronous. As the basal members of the Marion formation, the Herington and Luta limestones, have no distinguishing characters to mark them from the subjacent limestones excepting their position and thickness an attempt to fix the base of the Marion in a well at a considerable distance from its outcrops would be of doubtful value. However, the total thickness of the Marion from the top bed of the salt horizon to the first limestone of the basal beds below the salt, as shown from a large number of well logs, is fairly uniform. The thickness of this interval at Hutchinson is 393 feet; at Anthony, 404 feet; at Kingman, 415 feet; at Alva (Cos-

den test), 440 feet; at Gate, 420 feet; at Ashland, 375 feet; at McPherson, 410 feet; at Wilson, 425 feet.

Sub-Marion Formations: While there can be no doubt as to the presence of a considerable thickness of Lower Permian and Pennsylvanian strata in Central Kansas, no correlations will be attempted until further data are at hand. Merely as an example of the difficulties to be encountered, the thickness of the first limestone of the basal beds of the Marion used in compiling the figures above given is here shown for the same wells: At Hutchinson, 41 feet; at Anthony, 115 feet; at Kingman, 80 feet; at Alva (Cosden test), 290 feet, including one ten-foot break of shale; at Gate, 270 feet; at Ashland, 265 feet, with three small breaks of four, four and five feet of shale; at McPherson, approximately 105 feet; at Wilson, 25 feet.

As to the presence of sands in these lower formations in Central Kansas, the Hutchinson test well shows 114 feet of sands below the salt in a total depth of 1307 feet; Anthony none in 2335 feet; Kingman, 70 feet in 1410 feet; Alva (Cosden test), 135 feet from 2300 to 3000 feet; Gate, 20 feet in a total of 442 feet below the base of the salt, not including two sandy limestones with thicknesses of 83 and 52 feet, respectively; Ashland, 97 feet in a total of 818 feet below the salt; McPherson, no sands in a total depth of 2225 feet excepting streaks, sandy limestones and one thin layer of gray sandstone, possibly 10 feet at most; Wilson, 15 feet in a total of 125 feet below the salt.

As the number of prospect holes in Western Kansas and Eastern Colorado increases, it will be extremely interesting to trace the lithologic and stratigraphic changes from the geological section of the Pueblo district of Colorado to that shown in the Mineola and Ashland deep wells. In the Castle Rock folio of Colorado, Richardson gives the following section:

Permian:
- Lykins formation (red) ------ 225 feet

Pennsylvanian:
- Lyons sandstone (red) ------- 600 feet
- Fountain formation (red) ---- 2000 feet

Mississippian:
- Millsap limestone ----------- 85 feet

Ordovician:

Manitou limestone ---------- 60 feet plus or minus
Cambrian:
Sawatch sandstone ---------- 115 feet plus or minus
Pre-Cambrian:
Pike's Peak granite.

From Pueblo to Mineola, a distance of 250 miles, little is known of the stratigraphy of the Paleozoic rocks. At LaJunta, 64 miles east of Pueblo, a deep well boring shows Red Beds from 980 to 1703 feet, the bottom of the hole; at Syracuse and Santa Fe, wells 1000 and 1200 feet deep, respectively, ended in the Red Beds. At Mineola there are known to be 1680 feet of limestones, shales and sandstones below the base of the Red Beds; in Richardson's Castle Rock section, approximately 260 feet (to the granite). In the Colorado section, however, the entire thickness of the Pennsylvanian, 2600 feet, is red in color. Hence we may expect to see the same change from red to non-red Pennsylvanian in well logs of western Kansas and eastern Colorado as occurs in Oklahoma.

STRUCTURE.

General Statement: Certain factors brought out by a brief summary of the stratigraphy of Central Kansas might well be further emphasized in attempting to bring together such data as will help to reveal the broader structural features of the region.

(1) For the benefit of those making field examinations in Central Kansas to determine structure through the aid of dips and strikes of surface exposures of the formations, it is desirable to call attention to the following areas in which such examinations will be of practically no value so far as determining the position of the underlying rock strata: (a) the flood plains of the Arkansas and other large streams; (2) the sand dune region in general;* (c) the area of the McPherson Equus beds; (d) the Tertiary beds of this part of Kansas.

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*The writer has observed in several instances outcrops of the underlying formations even in the heart of the sand dune belt, where the sands had shifted in their migrations and exposed the bed rock beneath.

(2) All post-Paleozoic formations in this region were deposited after the underlying beds had been elevated above sea-level, warped and folded into somewhat the positions they occupy at present (structurally speaking), and then subjected to profound differential erosion throughout early and middle Mesozoic times. It would seem advisable, therefore, to proceed with greatest precaution in recommending drilling in the area of the outcrops of the Dakota and Benton groups unless all the evidence tended to show that structures mapped on a survey of such formations were superimposed over ancient lines of weakness (folded areas) in the Paleozoic strata.

Inclination of Tertiary Strata.

In Central Kansas, the Tertiary beds are not of sufficient importance structurally to merit much attention. Where indurated, the beds are usually observed to dip toward the east and southeast.

Inclination of Comanchean and Cretaceous Strata.

"On the Okahoma-Kansas line there are some 2200 feet of strata between the upper part of the Carboniferous and the base of the Cretaceous. At the Kansas-Nebraska line there are not to exceed 200 feet, while at the mouth of the Platte river the Dakota rests directly upon the upper surface of the eroded Carboniferous. In the Belvidere region the Cretaceous rocks below the base of the Dakota measure 250 feet, in Central Kansas they are not more than 100 feet, while at the Nebraska line the Dakota rests directly upon the Permian." (Dr. Gould, in Trans. Kans. Acad. Sci., Vol. XVII, p. 139).

The thickening of the rocks of both Mesozoic and Paleozoic eras to the south, and the extremely uneven erosion of the Carboniferous in Kansas during Triassic and Jurasic times are two very important facts to bear in mind in a study of both the stratigraphy and structure of Central Kansas.

Logan (Volume II of the Univ. of Kansas Geological Survey reports, page 205) states that the direction of the dip of the Cretaceous bed (in Kansas) is toward the northeast. An 80-mile section from Trego County to Mitchell County shows a dip of five feet per mile; another section from Wallace County to Jewell County, a distance of 170 miles, shows a dip of six

feet per mile; another from Santa Fe, in Haskell County, to Beloit, in Mitchell County, 190 miles northeast, gives a dip of a little more than six feet per mile in this direction. Udden (Amer. Geologist, Vol. VII, June, 1891, p. 344) concluded that the Dakota in Saline County dipped eight feet per mile to the east. These illustrations are sufficient to show that the dip of the Cretaceous, when measured over long distances, is nowhere very great. Locally, however, much greater dips are found.

In the southwestern Comanchean area, Prosser (Volume II, Univ. of Kans. Geol. Survey, pp. 165, 177 *et al.*) gives several sections, with elevations, and shows the dip here to vary from 9 to 14 feet per mile, in some places southeasterly in direction, in others northeasterly. In general, the dip of the Comanchean strata is coincident with that of the overlying Cretaceous, and the two systems are here discussed under one heading.

Inclination of Permian Strata.

"Throughout the whole of the Permian formation the general inclination of the strata is to the west. On account of the excessive thickening in the Flint Hills area the maximum dip doubtless is to the northwest. In some instances over miles of extent the inclination reaches from 14 to 16 feet per mile, but probably the average for the whole formations in the state is but little more than 10 to 12 feet. It is not known how far westward the inclination continues in this direction. The 'red beds' which immediately overlie the Permian are known to dip to the west as far as Great Bend, while the Cretaceous and Tertiary formations in the western part of the state are inclined to the east and northeast; but just where the division line is located between these two directions of inclination has not yet been determined." (Haworth, Vol. I, Univ. of Kans. Geol. Surv.)

Prosser (Vol. II, Univ. of Kans. Geol. Survey, pp. 160 and 178) states that the Day Creek dolomite near Ashland dips approximately six feet per mile to the north of east over a distance of five miles, and roughly nine feet per mile to the southeast in a five-mile section from Mt. Jesus to Messing's Bluff, in eastern Clark County. Approximate elevations of the Hutch-

inson salt horizon in the Alva, Cosden, Ashland, Mineola and Gate test wells are given as follows: 200 feet, 260 to 300 feet, 300 feet, 479 feet, 242-342 feet, respectively. Translated into terms of dip, the strata still retain the normally west dip from Alva to the Cosden test, the slight amount roughly four feet per mile over a distance of 17 miles, probably being due in part to the bowing up of the beds on the Whitehorse structure, on which the Cosden test was located. From the Cosden test to the Gate well, a distance of 62 miles, there is an east dip of about nine feet per mile. From Ashland to the Cosden test, the strata dip to the southeast at the rate of 11 feet per mile for the 53 miles; from Ashland to Gate, 26.5 miles, there is practically no dip in the strata; from Ashland to Mineola, the average dip for the 21 miles is 8 feet per mile to the southeast; and from Mineloa to Gate, the rocks dip southward at the rate of from 3.5 to 6 feet per mile for the 38.5 miles. These dips are in perfect accord with every observation recorded by Prosser in his study of the surface dips in the vicinity of Ashland, and show the great value of well records in structural determinations as a check on surface observations.

Apparently then, the trough of the geosyncline of the Plains lies somewhere between the Cosden test well and the Gate and Ashland wells, and much nearer the first mentioned well. As already stated, the east limb of the syncline is known to extend as far west as Dodge City.

In the north-central part of the state, in Marshall County, the average dip of the gypsum beds of the Garrison formation is about ten feet per mile to the northwest. Farther south, in Dickinson and Saline Counties, the dip of the gypsum beds of the Marion formation is nearly west, varying from 6 to 12 feet per mile. Still farther south, the dip of the formations may best be shown by a plat or discussion of the elevations of the Hutchinson salt horizon at the many points where salt and prospective oil wells have been drilled over the entire region of Central Kansas.

A north-south section from Anthony through Hutchinson to Ellsworth shows the elevation of the salt horizon to vary as follows:

Locality	Feet above sea-level Salt Horizon
Anthony	383
Rago	549
Kingman	833
Arlington	944
Hutchinson	1100
Nickerson	945
Sterling	940
Lyons	901
Ellsworth	812

An east-west section from Wellington west shows the inclination of the salt as follows:

Wellington	985	
Argonia	518	
Anthony	383	
Alva	-200	(below sea-level)
Cosden test	-250 plus or minus	(below sea-level)
Gate	242 to 342	

Trending northwest from the salt wells east of Hutchinson, the salt beds dip towards the northwest from 1120 feet, the maximum elevation of the salt at Hutchinson, to 945 feet at Nickerson and to 641 feet at Great Bend. West from Hutchinson the salt dips to 840 feet in elevation at Sylvia; southwest from Hutchinson the elevation drops from 944 feet at Arlington to 300 feet at Ashland. Expressed in feet per mile, the dip from Hutchinson south to Anthony is at the rate of a little more than 11 feet per mile for approximately 63 miles; from Hutchinson west to Sylvia, 9 feet per mile for 29 miles; northwest to Great Bend, a little over 8 feet per mile for 54 miles; from Wellington west-southwest to the Cosden test, better than 13 feet per mile for 90 miles. These figures, while approximate only, are sufficiently accurate to show the major structural features of this portion of Kansas.

Haworth, in the Mineral Resources of Kansas for 1900 and 1901, has traced an anticlinal ridge which would seem to extend at least half way across the state, using for his data, elevations of the top of the Mississippi limestone as shown by deep borings.

He states that this ridge "has been noticed as being prominent at many places. Now we have positive knowldge of its existence in the east end of the state, and in the vicinity of Hutchinson, as is clearly and positively shown by the geologic section published by Mr. M. Z. Kirk (Min. Res. Kans. 1898, pl. VI). This section shows that Hutchinson is immediately over a slight anticline, plainly apparent in the salt beds and the overlying Wellington shales, and that the latter thicken both to the north and south, indicating that the anticline was partly formed during the Wellington shales period. Whether this Hutchinson anticline is connected with the one farther east is yet undetermined, but quite likely it is, as the two correspond in position, direction and nature."

The writer has made a careful compilation and study of the numerous salt well records in the immediate vicinity of Hutchinson, and has found good evidence that Hutchinson lies at the apex of a well-defined anticline. This fold plunges to the southwest from Hutchinson and culminates east of the city in a well-defined terrace with slight east dips beyond, thus giving the structure a complete closure.

Undoubtedly a number of other structures favorable to oil and gas accumulation are now known in this part of Kansas by individual geologists, the writer being personally cognizant of three. At the present writing, however, no oil or gas in commercial quantities has ever been found in Kansas, to the writer's knowledge, west of Range 3 East (Potwin and Arkansas City districts), with the exception of the development north of the Blackwell district, on the Kansas side of the line.

Well Records in Central Kansas.

A few representative logs of wells are given below, and the following list of publications may be consulted by those desiring information regarding other well records in this general region:

Mineral Resources of Kansas for 1898,

- Anthony well,
- Kingman well,
- Hutchinson well,
- Lyons salt shaft,
- Kanapolis well,

Little River well,
Sterling well,
Wilson well.

Transactions Kans. Acad. Science Vol. XV (1898),
Wichita well.

Professional Paper No. 32, U. S. G. S. (1905),
Wells of west-central Kansas.

Bulletin No. 298, U. S. G. S. (1906),
McPherson and other deep wells.

Bulletin No. 19, Okla. G. S. (1917),
Alva and other deep wells.

Bulletin No. 30, Okla. G. S. (1917),
Gate, Enid and other deep wells in the red beds.

Log of Ben Blanchard well at Hutchinson, in section 26, T. 23 S., R. 6 W.; Messrs. Palmer and Davis, drillers. Drilled in 1887.

	Thickness Feet	Depth Feet
Sand, drift and soil	146	146
Red shale	26	172
Shale	2	174
Red shale	76	250
Blue shale	12	262
Gray shale	78	340
Red shale	10	350
Black shale	15	374 ?
Red shale	9	383
Black shale	99	482
Salt	18	500
Shale	8	509 ?
Shale and salt	3½	512½
Salt	13	525½
Shale	15	540½
Salt	11	551½
Shale	7	558½
Salt	10	568½
Shale	3½	572
Salt	27	599
Flint rock	2	601
Salt	47	648
Shale	3	651
Salt	138	789
Shale	13	802
Salt	8	810
Shale	37	847
Gypsum	28	875
Lime	38	913
Marble	3	916
Clay	1	917
Shale	4	921
Gypsum	8	929
Black shale	5	934
Limestone	6	940
Red shale	2	942
Limestone	19	961
Shale	11	972
Limestone	10	982
Black sandstone	7	989
Limestone	24	1013
Sandstone	27	1040
Shale	22	1062
Limestone	14	1076
Shale	25	1101
Red sandstone	45	1146
Limestone	12	1158
Shale (small seam coal)	36	1194
Limestone	26	1220
Sandstone	35	1255
Limestone	10	1265
Shale	30	1295
Limestone	5	1300
Shale	7	1307

Log of Mineola, Kansas, deep well, in Section 10, Township 30 South, Range 25 West.

	Thickness Feet	Depth Feet
Black soil	5	5
Yellow clay, water	75	80
Gray sand, water	41	121
Yellow gyp	4	125
Red rock	5	130
Blue slate	143	273
White lime	2	275
Blue slate	10	285
Gray sand, water	35	320
Blue slate	60	380
Red rock	45	425
Red sand, water	15	440
Red rock	30	470
Gray sand, water	15	485
Red rock	15	500
Red sand	15	515
Red rock	60	575
Gray sand	3	578
White slate	7	585
Red rock	35	620
Gray lime	15	635
Red rock	13	648
Gray lime	12	660
Red rock	3	663
Gray lime	12	675
Red rock	5	680
White lime	10	690
Blue slate	60	750
Gray lime	15	765
Red slate	15	780
Salt	158	938
Red rock	22	960
Red lime	10	970
Salt	30	1000
Gray sandy lime	8	1008
Red rock	7	1015
Red limy shale	50	1065
Salt	25	1090
Shelly red rock	50	1140
Salt	8	1148
Gray sand	4	1152
Red rock	158	1310
Gray lime	20	1330
Red Rock	10	1340
Gray sandy lime	10	1350
Red rock	70	1420
Gray lime	5	1425
Red rock	10	1435
Gray sand	20	1455
Red rock	21	1476
Gray sand	24	1500
White lime	8	1508
Brown slate	4	1512
Gray sandy lime	14	1526
Salt	24	1550
White slate	10	1560
Gray lime	20	1580
Brown shale	75	1655
Red rock	15	1670
Gray lime	5	1675
Red rock	45	1720
Gray slate	8	1728
Red rock	192	1920
Gray lime	5	1925
Blue slate	25	1950
Gray lime	15	1965
White slate	20	1985
Brown shale	8	1993
Blue slate	52	2045
White slate	20	2065
Gray lime	3	2068
Dark slate	7	2075
Salt	95	2185 ?
Gray slate	7	2192
Gray, broken	12	2204
Gray lime	21	2225
Salt	25	2250
Gray slate	20	2270
Salt	30	2300
Black slate	3	2303
Gray lime	12	2315
Blue slate	25	2340
Gray lime	10	2350
Salt	15	2365
Gray sandy lime	70	2435
Blue slate	8	2443
Gray lime	27	2470
Black slate	10	2480
Gray lime	15	2495
Blue shale	15	2510
Black slate	20	2530
Gray lime	15	2545
Black shale	20	2565
Gray lime	50	2615
Black shale	4	2619
Gray lime	29	2648
Black slate	12	2660
6% Paraffin	at	2676
Gray lime	20	2680
Light slate	5	2685
Gray lime	20	2705
Brown slate	10	2715
Black lime	25	2740
Black shale	35	2775
Gray sandy lime, water	65	2840

	Thickness Feet	Depth Feet
Red rock	15	2855
Gray lime	65	2920
Gray shale	10	2930
Gray lime	15	2945
Gray sandy lime	20	2965
Gray lime	35	3000
Paraffin and red slate	6	3006
Red rock	12	3018
Gray lime	42	3060
Gray sandy lime	20	3080
Black slate	10	3090
Gray sand	10	3100
Gray lime	15	3115
Black slate	5	3120
Red rock	5	3125
Gray lime	45	3170
Black slate	3	3173
Gray lime	55	3228
Black slate	5	3233
Gray lime	4	3237
Gray lime	23	3260
Red rock	4	3264
Gray lime, water	18	3282
Gray sandy lime	318	3600

Log of Turkey Track Oil & Gas Company, at Ashland, Kansas, in Section 17, Township 31 South, Range 22 West.

	Thickness Feet	Depth Feet
Soil	10	10
Sand	15	25
Red shale	45	70
Water sand	10	80
Red shale	100	180
Water sand	30	210
Red shale	25	235
(Set 12.5" casing)		
Red shale	10	245
Limeshells and chalk	25	270
Granite	15	285
Red shale	10	295
Sand	5	300
Red sandy shale	10	310
Salt	225	535
Red shale	90	625
Salt	5	630
Red shale	60	690
White sandy shale	5	695
Salt	5	700
Red shale	50	750
Red sandy shale	30	780
Red and blue sandy shale	195	975
White sandy lime	5	980
(Set 10" casing)		
Red and blue shale	195	1175
Lime	15	1190
Red shale	30	1220
Salt	15	1235
Blue shale	10	1245
Red shale	145	1390
Blue shale	40	1430
Red shale	80	1510
Blue shale	10	1520
Red shale	40	1560
Blue shale	40	1600
Gray shale	20	1620
Blue shale	20	1640
Sandy shale	8	1648
Blue shale	32	1680
Gray shale	10	1690
Sandy shale	5	1695
Lime shell	5	1700
Blue shale	5	1705
Red salt	7	1712
Lime shell	8	1720
Blue shale	20	1740
Lime	5	1745
Blue shale	10	1755
Light sandy shale	40	1795
Dark shale	15	1810
Salt	45	1855
Lime	5	1860
Salt	20	1880
Lime shell	5	1885
Salt cryst.	10	1895
Gray broken lime	5	1900
Salt	20	1920
Light shale	10	1930
Salt	30	1960
Lime shell	10	1970
Sandy shale	30	2000
Salt	20	2020
Salt cryst.	5	2025
Broken lime	10	2035
Salt	20	2055
Dark slate	10	2065
Lime	10	2075
Sandy shale	20	2095
Lime	45	2140
Dark shale	15	2155
Blue sandy shale	15	2170
Salt	15	2185

	Thickness Feet	Depth Feet
Gray lime	65	2250
Gray shale	4	2254
Gray lime	46	2300
Gray shale	5	2305
Hard gray lime	65	2370
Blue shale	4	2374
Gray lime	76	2450
Red shale	3	2453
Sandy lime	32	2485
Sand	10	2495
Hard lime	30	2525
Sand	10	2535
Gray lime	15	2550
Blue shale	15	2565
Gray lime	20	2585
Sandy lime	5	2590
Light sand	5	2595
Dark sand	5	2600
Light sand	10	2610
Brown sand	10	2620
Red shale	5	2625
Brown sand	5	2630
Gray lime	8	2638
Gray sand	17	2655
Sandy shale	10	2665
Gray lime	10	2675
Sandy lime	15	2690
Gray sand	10	2700
Gray lime	20	2720
Shale	5	2725
Gray lime	10	2735
Gray sandy lime	15	2750
Gray lime	25	2775
Blue shale	10	2785
Red shale	5	2790
Gray lime	10	2800
Blue shale	25	2825
Lime	20	2845
Sand	15	2860
Brown shale	30	2890
Blue shale	10	2900
Gray lime	20	2920
Sandy shale	15	2935
Broken lime shell	20	2955
Brown shale	10	2965
Lime	20	2985
Brown shale	10	2995
Gray sandy lime	8	3003

Log of Wellington Oil & Development Company well in the northeast quarter of Section 29, Township 32 South, Range 1 West (courtesy of Mr. C. F. Martin, Secretary).

	Thickness Feet	Depth Feet
Surface soils, etc.	84	84
Blue slate	146	230
Lime	3	233
Red rock	12	245
Shale	63	308
Lime	2	310
Salt	5	315
Slate	51	366
Salt	32	398
Lime	2	400
Slate	6	406
Lime	16	422
Slate	11	433
Lime	22	455
Slate	10	465
Red rock	7	472
Lime	4	476
Slate	4	480
Lime	8	488
Slate	4	492
Red rock	4	496
Slate	19	515
Lime	15	530
Slate	32	562
Lime	30	592
Sandy lime	4	596
Shale	2	598
Lime	28	626
Red rock	2	628
Slate	3	631
Lime	4	635
Slate	18	653
Lime	32	685
Red rock	10	695
Blue slate	5	700
Lime	10	710
Slate	15	725
Sand	20	745
Broken sand	5	750
Slate	7	757
Red rock	9	766
Lime	4	770
Slate	5	775
Lime	45	820
Sand, water	34	854
Lime, water	63	917
Sand	13	930
Lime	4	934

	Thickness Feet	Depth Feet
Slate	4	938
Lime	31	969
Slate	3	972
Lime	3	975
Red rock	3	978
Lime	3	981
Slate	4	985
Sand, water	13	998
Slate	6	1004
Sand	13	1017
Lime	8	1025
Shale	11	1036
Red rock	9	1045
Lime	25	1070
Slate	6	1076
Lime	74	1150
(Set 12½′ casing)		
Lime	48	1198
Slate	12	1210
Lime	10	1220
Broken lime	45	1265
Shale	8	1273
Lime	8	1281
Shale	7	1288
Lime	7	1295
Slate	11	1306
Lime, much water	17	1323
Sand	9	1332
Lime	4	1336
Slate	5	1341
Lime	22	1363
Slate	11	1374
Lime	12	1386
Slate	11	1397
Lime	25	1422
Slate	14	1436
Lime	30	1466
Slate	3	1469
Lime	6	1475
Broken lime	12	1487
Shale	5	1492
Sand, water	15	1507
Shale	17	1524
Lime	23	1547
Slate	7	1554
Lime	3	1557
Red rock	3	1560
Slate	7	1567
(Set 10″ casing)		
Lime	5	1572
Slate	10	1582
Sand	8	1590
Slate	13	1603
Red rock	12	1615
Slate	19	1634
Lime	5	1639
Shale	26	1665
Lime	9	1674
Sand, water	16	1690
Slate	40	1730
Lime	4	1734
Blue shale	24	1758
Lime	2	1760
Blue shale	10	1770
Lime	46	1816
Slate	8	1824
Lime	5	1829
Blue slate and shells	22	1851
Lime	14	1865
Sandy lime, water	14	1879
Lime	21	1900
Blue slate	5	1905
Lime	3	1908
Sandy slate, water	14	1922
Lime	4	1926
Blue slate	16	1942
Lime	10	1952
Blue slate	25	1977
Lime	34	2011
(Set 8″ casing)		
Lime	12	2023
Shale	4	2027
Sandy lime	43	2070
Black shale	5	2075
Blue shale	10	2085
Lime	3	2088
Blue slate	32	2120
Lime	3	2123
Brown shale	14	2137
Broken sand	28	2165
Brown shale	30	2195
Lime	5	2200
Brown shale	10	2210
Sand, two bailers of water	10	2220
White shale	12	2232
Flint	24	2256
Lime	29	2285
Black shale	5	2290
Sandy lime	10	2300
Brown shale	10	2310
Sandy lime, with water	150	2460
Black slate	4	2464
Lime	5	2469
Black shale	2	2471
Lime	2	2473
Black shale	4	2477
Lime	3	2480
Black shale	15	2495
Lime	8	2503
Sandy shale	14	2517
Lime	4	2521
Sandy shale	11	2532

	Thickness Feet	Depth Feet
Lime	4	2536
Blue shale	11	2547
Red rock	1	2548
Blue shale	6	2554
Lime (underreamed and set 8" casing at 2565)	12	2566
White shale	2	2568
Lime	19	2587
Blue shale	6	2593
Lime	8	2601
Sand	25	2626
Lime	24	2650
Blue shale	23	2673
Lime	3	2676
Blue shale	109	2785
Lime	5	2790
White shale	18	2808
Brown shale	41	2849
Lime	11	2860
Blue slate	25	2885
Lime	6	2891
White slate	10	2901
Gray sand, water	24	2925
Blue slate	5	2930
Sandy lime	15	2945
Broken shale	120	3065
Brown shale	118	3183
Lime	12	3195
Sand	35	3230
(Set 6 and 5/8" casing)		
Lime	22	3252
Sand	55	3307
Lime	43	3350
Black shale	3	3353
Lime	7	3360
Black shale	2	3362
Lime	13	3375
Black shale	2	3377
Broken lime	63	3440
Blue slate	28	3468
Lime	5	3473
Blue slate	4	3477
Broken white sand	55	3532
Lime	4	3536
--(6 and 5/8" casing under-reamed to 3540')		
Blue slate	13	3549
Lime	9	3558
Brown shale	7	3565
Lime	4	3569
White slate	2	3571
Broken lime	6	3577
Brown shale	3	3580
Blue slate	5	3585
Lime	2	3587
Blue slate	13	3600
Sandy shale	37	3637
Lime	7	3644
Blue slate	26	3670
Lime	4	3674
Sandy slate, water	11	3685

Discussion.

D. W. Ohern: That was a very interesting paper. I notice, however, that the speaker failed to mention any connection between the great bend of the Arkansas River at that place and the structure he has worked out. Every one who has looked at a map of the Arkansas River is impressed with the bend in the river. I assume it is due to structural causes. We know that it is the habit of this field to reverse the order of things obtained in the Appalachian field in regard to structure. I ask if the north bend of the Arkansas River might have been due to structural conditions.

Mr. Perrine: There are several articles which answer his article perfectly. A geological map of Kansas shows the Dakota sandstone outcropping along the river from eastern Ford County to Great Bend. The river follows the Dakota formation because this formation is very easily corraded. The river instead of con-

tinuing eastward from Great Bend, was forced southward again owing to the higher elevation of the Flint Hills to the north.

Dr. Haworth states in one report without a doubt some time in the past the Arkansas River followed straight east from Ford County through Kiowa, Pratt and Kingman Counties, probably passing out of the State not far from its present location.

GEOLOGIC HISTORY OF THE CRYSTALLINE ROCKS OF KANSAS.

By RAYMOND C. MOORE, *Lawrence, Kansas.*

The presence of crystalline rocks at comparatively shallow depths below the surface in a number of wells of North Central Kansas and the adjacent portion of Nebraska has been indicated recently and described in some detail by Taylor[1], Powers[2] and Wright[3]. Careful investigations by the writer, with the assistance of his colleague, Dr. Winthrop P. Haynes, which have included practically all of the reported occurrences of the crystalline rocks, sustain wholly the general conclusions of previous observers. There is no longer the question concerning the identification of the rock encountered by the drill as a typical medium to coarse-grained granite.

It is unnecessary to recount the character of each well[4]. The data concerning them may be summarized in the following table:

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[1]Taylor, Chas. H., The Granites of Kansas: Bull. Southwestern Ass'n Petroleum Geologists, vol. 1, pp. 111-126, Feb., 1917.

[2]Powers, Sidney, Granite in Kansas: Am. Jour. Sci., 4 ser., vol. 44, pp. 146-150, August, 1917.

[3]Wright, Park, Granite in Kansas Wells: Bull. Amer. Inst. Mining Eng., No. 128, pp. 1113-1120; August, 1917.

[4]For a detailed description of the wells with logs, petrographic examination of cuttings, etc., see Moore, R. C., and Haynes, W. P., The Crystalline Rocks of Kansas; Oil & Gas Resources of Kansas; Kans. State Geo. Survey, Bull. 3, pp. 140-173, 1917.

Summary of wells in central Kansas which have encountered granite.

Location	County	Nearest town	Farm	Drilled by—	Formation at surface.	Elevation, feet.	Depth to granite, feet.	Depth of well, feet.	Amount of granite penetrated, feet.
34- 2-12	Nemaha	Seneca				1,150	586	746	160
34- 6-11	Pottawatomie	Onaga	Rokes	Empire Gas & Fuel Co.	Elmdale shale		960	1,810	850
2- 7- 5	Riley	Winkler	Droll	Gypsy Oil Co.			2,385	2,520	135
12-10-10	Wabaunsee	Wamego	Miller	Ca'ter Oil Co.			2,300+	2,400+	(?)
28-10- 9	Riley	Zeandale	Bardwell 1		Eskridge shale	1,050	928	1,020	92
26-10- 9	Wabaunsee	Zeandale	Bardwell 2		Elmdale shale	1,075	958	1,093	135
1-11- 9	Wabaunsee	Wabaunsee	Root	Empire Gas & Fuel Co.	Eskridge shale	1,069	1,180	1,990	810
24-15- 7	Morris	Kelso	Whiting	Echo Oil Co.	Matfield sha'e	1,384	2,512	2,551	39
34-17- 7	Morris	Hymer	Moffett	Empire Gas & Fuel Co.	Florence flint	1,560	2,506	2,608	102
34-19- 7	Chase	Elmdale	Poor Farm	DeLaat & Shepard	Elmdale shale	1,203	1,805	2,525	720
2-20- 7	Chase	Elmdale	Kaufman	Empire Gas & Fuel Co.	Garrison shale and limestone	1,388	1,890	3,055	1,165
14-23- 5	Butler	Burns	Lilly	Roxana Petroleum Co.	Fort Riley limestone	1,480	2,331	2,500	169
17-25-15	Woodson	Yates Center		Aurora Oil & Gas Co.	Lawrence shale		2,555	2,591	36

The "granite wells" are arranged in a belt trending from north-northeast to south-southwest. Their alignment, with the exception of a few wells which only encounter the granite at greater depths, is rather remarkably straight. The distance from the northernmost well in Nebraska where crystalline rocks have been encountered to the southernmost in Butler County, is about 175 miles.

As determined by drilling the granite appears to have the form of an elongated ridge, with a very uneven surface, which slopes from about 600 feet above sea level at the northern end to sea level just south of Zeandale, a distance of about 65 miles. From this point southward the slope is much steeper and a depression in the top of the ridge to 1,100 feet below sea level is reached in about thirty-five miles. The surface then rises to about 500 feet below sea level at Elmdale, and slopes gradually to the south until it is about 900 feet below sea level near Burns, about 30 miles from Elmdale. From here the drop is rapid to the south, because a well near Potwin reached 1,800 feet below sea level without encountering granite. The highest part of the ridge which has thus far been indicated by well borings is in Nemaha County, Kansas, and the adjacent portion of Pawnee and Richardson Counties, Nebraska. Unfortunately, deep well records in closely adjacent districts to the north are not available, but a well drilled to 3,010 feet, about 2,050 feet below sea level, at Nebraska City, on Missouri River, in Otoe County, Nebraska, did not encounter granite. This well is less than 50 miles in a direction slightly east of north of Dubois, Pawnee County, Nebraska, along a line which is almost exactly a continuation of the trend of the granite ridge. This then indicates a northward slope of the granite surface of more than 2,500 feet in this distance.

Origin of the Crystalline Rocks.

Petrographic study of the drill cuttings from the "granite" wells has established the fact that true crystalline rocks, chiefly granite, have been encountered. Granite is an igneous rock which was once in a molten state and has cooled more or less slowly under pressure below the surface of the ground. A large mass of granite such as outlined by the drilling in Kansas may have come into its present position in two ways. (1) It may

have been intruded in a molten state into the sedimentary rocks now overlying and surrounding it, or (2) it may be a part of the deeply eroded Pre-Cambrian basement of crystalline rocks on which the sedimentary rocks of the region have been deposited.

(1) If the granite mass is an igneous intrusion into the sedimentary rocks with which it is in contact, it must have forced its way upward into them as molten lava, breaking off and fusing fragments of the strata and finally cooling and crystallizing. The effects of an intrusion of this sort are apparent both in the granite itself and in the rocks which are intruded. The crystals near the contact border of the granite are much smaller than those farther within the mass, and the rocks intruded are greatly altered by the various gaseous and liquid emanations and the enormous heat from the molten mass. Large intrusions are almost invariably accompanied, also, by pronounced structural disturbances of the adjacent rocks, including more or less close folding, and in some cases extensive faulting.

A petrographic study of samples taken from the border and at various depths within the granite mass fails to show any marked difference in the size of the crystals such as would result from more rapid cooling near the contact border. Examination also of the strata which are in contact with the granite shows only normal sediments, unaltered sandstones and shales, which have not been changed in any way by heat or by chemical action. More detailed information than the well logs is available for some of the wells. Haworth[1] reports a 5 to 10 foot bed of shale immediately above the granite in the Zeandale wells, from which he collected samples. These were studied in detail by Dr. W. H. Twenhofel and reported by him to be an ordinary slightly compacted mud and sand deposit of a type common to the Pennsylvanian beds in Kansas. Twenhofel not only found no evidence of any metamorphism of the sediments, but he was able to identify numerous poorly preserved fragments of gastropod shells which showed no signs of distortion other than produced by the weight of the overlying rock. Taylor[2] reports the presence of a normal

[1]Haworth, Erasmus, The Crystalline Rocks of Kansas: Kans. Univ. Geol. Survey, Bull. 2, pp. 26-27, 1915.

[2]Taylor, Charles H., The Granites of Kansas: Bull. Southwestern Assn. Petroleum Geologists, vol. 1, p. 116, 1917.

red shale above the granite in the Lilly well, in which he identified small fragments of flesh-colored feldspar and a few fragments of quartz.

The strata above the granite ridge in Central Kansas are very slightly warped into an elongate anticline or dome, the longer axis of which is parallel to the trend of the granite ridge. It is owing to this relation, indeed, that so large a number of wells have been drilled into the granite. There is, however, an entire absence of the more intense folding and extensive faulting which might well be expected in the intrusion of a great granite mass at least 165 miles long and from 10 to 25 miles wide, as indicated by drilling records. No faulting of the Pennsylvanian strata in any part of Central Kansas has been described. Since erosion of the overlying beds has brought the surface of the granite within 600 to 700 feet of the surface in at least a part of the district, this lack of structural disturbance indicates that the granite has not been intruded into the adjacent strata since their deposition.

All of the features observed, both in the granite and in the strata immediately above the granite, oppose the hypothesis of an intrusive origin for the granite.

(2) It is possible that the granite which has been encountered in Central Kansas forms a part of the crystalline basement of Archeozoic and Proterozoic rocks which underlies the entire Great Plains. In this case the granite is of great geologic antiquity, and instead of having come into its present position in a molten state after the Pennsylvanian rocks had been deposited, it is the uneven, deeply eroded floor on which the Pennsylvanian beds have been laid down. If this interpretation is correct, there should be evidence, probably not less conclusive than in the case of an intrusion, both in the granite mass and in the stratified rocks overlying the granite. The size of the crystals and general texture of the granite should be much the same throughout, except that if long exposed to weathering agencies before burial by accumulating sediments, the outer portion of the granite might be more or less altered and decayed. The sedimentary rocks which surround and overlie the granite should contain no marks of

alteration by the gaseous and liquid emanations and the heat of the granite, but on the contrary might contain fragments of various sizes which had been derived by erosion from the granite They should show an absence of pronounced structural displacements such as folding or faulting, which are, in general, associated with intrusions of large granitic masses. It is seen that the evidences of an ancient crystalline basement are almost directly opposite to those of an intrusion.

Examination of the size of the crystals and of the general texture of specimens of the granite from the border and deep within the granite mass shows almost identical characters, as has already been indicated. A slight but progressive variation in color from the top of the granite downward has, however, been noted by Taylor[1], which is interpreted to represent the ancient weathering of the granite. According to observation of the writers, also, specimens of granite near the border of the mass contain a larger proportion of weathered minerals.

The sedimentary rocks which are in contact with the granite in no case show any indication of metamorphism, a fact which in the case of so large an igneous mass may be accepted as adequate proof that the granite is not intrusive. On the other hand, some of the material in the Pennsylvanian rocks above and around the granite appears to have been derived from it or a similar exposed crystalline body. The material immediately overlying the granite in almost every case is clastic in origin, and in a number of cases it contains a considerable proportion of feldspathic debris. Mr. R. A. Conkling, chief geologist of the Roxana Petroleum Company, reports[2] that gravel overlying the granite in the Hymer well contains water-worn pebbles of quartz and chert up to 2 inches in diameter[3]. It is also perhaps noteworthy that

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[1]Taylor, Charles H., The Granites of Kansas: Bull. Southwestern Assn. Petroleum Geologists, vol. 1, p. 117, 1917.

[2]Personal communication.

[3]It seems to the writer that the identification of water-worn chert pebbles is difficult and somewhat uncertain. If they have, indeed, been derived from the weathering of some older rock, this might be Mississippian or perhaps an older system which is not now present in the area.

a larger proportion of clastic material is found in the lower depths of wells which have been drilled in the vicinity of the granite ridge. Twenhofel[1] has described the occurrence of large numbers of granite porphyry bowlders up to 7 feet in diameter in the Weston shale member of the Douglas formation, near Rose, Woodson County. Twenhofel considers that the bowlders were deposited contemporaneously with the shale, being transported by the agency of ice. No satisfactory explanation of the place of origin of the bowlders has been suggested, and it is apparent that although much nearer the granite area of Central Kansas than any other, the locality at which the bowlders have been observed is many miles from the belt of "granite wells." Sidney Powers (Granite in Kansas: Am. Jour. Sci., ser. 4, vol. 44, p. 146, 1917) has suggested that the bowlders were derived from a closely adjacent mass of the granite basement which was exposed at the time of deposition of the shale. However, the granite basement does not rise to the horizon of the Weston shale, so far as known, at any point nearer than Central Kansas. A deep well recently drilled at Yates Center, six miles northwest of the bowlder locality, shows that the crystalline basement is more than 2,500 feet beneath the surface here. As already indicated, there is a complete absence of any important structural displacement of the rocks overlying the granite.

The evidence seems to indicate clearly that the granite which has been encountered in the wells of Central Kansas is an uplifted ridge forming an essential part of the crystalline basement which underlies all the stratified rocks of the region[2]. The geologic importance as well as the economic interest which attaches to this buried protuberance of the crystalline floor makes desirable some special designation by which convenient reference to it may be made. On account of the location of the wells which apparently were first drilled into the granite in the valley of Nemaha River and in Nemaha County, as well as because in this region the

[1]Twenhofel, W. H., Granite bowlders in (?) Pennsylvanian strata of Kansas: Am. Jour. Sci., ser. 4, vol. 43, pp. 363-380, 1917

[2]Recent papers describing the granite of Kansas contain a general agreement with this view.

granite appears most nearly to approach the surface, it is proposed to name the buried granite mountain ridge of Central Kansas the Nemaha Mountains. As defined by drilling at present, the buried Nemaha Mountains are nearly 170 miles long, trending from northeast to southwest, 10 to 25 miles wide and from 1,500 to 2,500 feet above the surrounding granite basement.

Age of the Crystalline Rocks.

There is at present little definite evidence concerning either the age of the granite in Central Kansas or the time when it came into its present position. It is very probable, however, if not absolutely certain, that the Kansas granite is equivalent to the granites exposed at various points in the surrounding region. These are in all cases Pre-Cambrian in age, and there seems to be no good reason for believing the granite which has been found in Kansas to be other than Pre-Cambrian.

Concerning the time when the granite was uplifted into its present position there is more question. Beds of Cambrian and Ordovician age, including also in some areas regular sequences of Silurian, Devonian and Mississippian strata, overlie the granite in the places where it is exposed, proving that during these times the granite was covered by the sea. In Kansas the crystalline basement of the eastern part of the State is covered by Cambrian, Ordovician, Mississippian and Pennsylvanian beds, but the granite of Central Kansas is overlain by rocks of Pennsylvanian age only. The absence of rocks older than the Pennsylvanian, in the latter case, may be accounted for by the supposition either that they have never been deposited in this region, or that they have been deposited as in neighboring areas but have been removed by subsequent erosion. The second alternative seems almost certain, for not only is there a general lack of clastic material in many of the beds of these systems in Eastern Kansas, but a relatively small granite mass such as that of Central Kansas must in no long time have been worn entirely away. It is confidently believed that the granite was not an elevated land mass in early Mississippian time, for the seas of the Osage epoch from New Mexico to Northern Iowa and Illinois were remarkably clear, as evi-

denced by the almost complete lack of clastic material in the Osage deposits. The Mississippian sea entirely covered the higher Ozark land[1] in Missouri, and may be presumed to have flooded all of the Kansas region. However, the Mississippian does not now overlie the Nemaha granite in Central Kansas, and it must be assumed that if Mississippian strata did at one time cover it they have been removed by erosion before deposition of the Pennsylvanian in the district. This indicates a rather pronounced though local deformation in Central Kansas in late Mississippian or early Pennsylvanian time, followed by rapid erosion which removed all of the sediments covering at least the top of the granite. Evidence from adjoining areas appears to support such an assumption. The Mississippian of Southeastern Kansas and about the Ozark highlands was exposed and deeply eroded before Pennsylvanian sedimentation in the region, although no deformative movement other than tilting of the beds has been recognized. To the south, however, especially about the Arbuckle and Wichita mountains of Oklahoma, there appear to have been very pronounced orogenic movements at this time. In the Arbuckle mountains there was extensive faulting and folding, in which 6,000 to 8,000 feet of sediments were uplifted into a mountain area of considerable relief[2]. It is very possible that the considerable adjustment of the Southern Oklahoma region was accompanied by a similar movement in Kansas. Pennsylvanian and Permian sediments completely buried the Nemaha mountains, probably the Wichitas and perhaps the Arbuckles. The cover of later deposits has been largely removed from the southern mountain belts, but still buries the northern. While not conclusive, it seems most probable that the Nemaha mountains were uplifted in late Mississippian or early Pennsylvanian time.

Geologic History of the Crystalline Rock Area.

In concluding the discussion of the buried granite of Central

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[1]Bridge, Josiah, A study of the faunas of the residual Mississippian of Phelps County (Central Ozark region), Missouri: Jour. Geology, vol. XXV, pp. 558-575, 1917.

[2]Taff, J. A., Preliminary report on the geology of the Wichita and Arbuckle mountains, in Indian Territory and Oklahoma: U. S. Geol. Survey, Prof. Paper 31, p. 37, 1904.

Kansas it will be of interest to summarize the geologic history of the region so far as indicated by present knowledge. Data are unfortunately by no means so complete as desirable, since the older rock divisions are not exposed in Kansas, but sufficient is known from a study of deep-well records and from an examination of closely adjacent areas in which the older beds are exposed to form a fairly consecutive though general account of the chief geologic events. These will be described under the head of their respective geologic divisions.

Archeozoic Era.

The earliest time of which evidence has probably been found in the Kansas region is the Archeozoic, to which are provisionally referred the crystalline rocks which have been encountered in deep borings within the State. Proof that the exposed crystalline rocks of surrounding regions are Archeozoic in age is by no means conclusive, but this is most likely. Presuming the correctness of this correlation, Archeozoic time in this area may be pictured as a period of inconceivably long duration, in which sediments were accumulating as in other areas, but characterized especially by great mountain-making movements accompanied by enormous intrusions of granite and other igneous rocks. From samples of the crystalline basement which have been obtained in Kansas wells it seems that there were later intrusions of a basic magma into the granite, forming diabase dikes, and at least in some places intrusions of an acid magma into small fissures, forming dikes of quartz porphyry. It is possible that some of the intrusions are Proterozoic or younger but all of the igneous complex was probably formed before the Cambrian. The granite, having cooled and crystallized deep below the surface, was laid bare and extensively eroded, in the latter part or probably at the close of the Archeozoic Era.

Proterozoic Era.

No definite record of the Proterozoic is found in Kansas, but rocks which in all probability are referrable to it are known in the surrounding areas of Pre-Cambrian rocks. These are more or less altered sedimentary rocks for the most part, and are chiefly clastic in origin, having been derived from the weathering

and erosion of exposed masses of Archeozoic rocks. The hard quartz sandstone or quartzite above the granite in the Yates Center, Neodesha, and perhaps in the Iola wells is either late Proterozoic or early Cambrian. Exposures of similar quartzite in South Dakota, Iowa and Minnesota are regarded as Proterozoic in age. The era was probably one of extensive erosion and deposition, the sediments in the Kansas region being for the most part clastic in character. As in other regions, there may have been great mountain uplifts, accompanied by extensive folding and faulting of the rocks, perhaps associated with considerable igneous activity. Before the beginning of Cambrian sedimentation there was very widespread, long-continued erosion, in which the country was reduced to a nearly level plain. This is inferred from the close accordance of the stratification of the Cambrian beds with the very even surface of the crystalline floor beneath.

Paleozoic Era.

The Paleozoic, as recorded by deposits in the Great Plains country, was a long interval of alternate deposition and erosion in which very thick accumulations of all kinds of sediments were laid down and in part carried away again. The deposits contain fossil remains of the life which existed at the time they were formed, and may be interpreted in a much more detailed manner than any preceding part of geologic time. The Paleozoic was a time of relative quiet in the Kansas region, not marked by igneous intrusions on a large scale, nor for the most part by mountain-making movements. The main events of the Era so far as they are known, may be summarized briefly under the head of its various subdivisions.

Cambrian: In early and perhaps middle Cambrian time Kansas was a lowland upon which the sea was gradually encroaching. Strata of Lower and Middle Cambrian age are not found in the central and upper Mississippi valley, but the Upper Cambrian sea extended very widely to the north and west. In late Cambrian time, therefore, although strata of this age have not certainly been identified in the deep well borings of Kansas, the sea doubtless flooded the entire territory now included in the State, and deposits, largely clastic in character, were laid down.

Ordovician: There seems to have been no important interruption of sedimentation in the Ozark region between the Cambrian and Ordovician periods, and the sea may be assumed to have remained over all of Kansas throughout the great portion of the period. The chief deposits of the Ordovician seas in this region were very thick limestones, now largely changed to dolomites, but beds of sandstone and shale were also formed. The thickness of the Ordovician sediments in many parts of Kansas is probably not in excess of 1,500 feet, but in neighboring regions, as the Arbuckle and Wichita mountains of Oklahoma, limestones up to 6,000 feet in thickness were deposited.

Silurian and Devonian: No strata of Silurian or Devonian age have been recognized on the west side of the Ozarks[1], though limestones of Middle Silurian (Niagaran) age and sandstone and shale of possible Upper Devonian age are known in Northeastern Oklahoma, Northern Arkansas and northeast of the Ozarks. If Kansas was submerged by the sea at any time during these periods, there is no present indication of the fact. It is very possible that the sea may have advanced at least for short intervals over Kansas, but that in the succeeding times of emergence the deposits laid down were eroded away; or the buried deposits may be present within the State but undiscovered or unrecognized.

Mississippian: In early Mississippian time the sea began a new inundation of the land. About the borders of the Ozark highland, which was then an island, clastic sediments consisting of mud and sand were deposited, but it is possible that in Kansas, which may previously have been invaded by the sea, the deposits of early Mississippian time were essentially calcareous. Certainly

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[1]Shepard, E. M. (Geology of Greene County: Mo. Geol. Survey, vol. 12, 1898) has described thin local deposits of magnesian limestone and shale in Southwestern Missouri, but recent unpublished studies by the author make very doubtful this correlation. It is believed, also, that the sandstone (Sylamore) and shale (Chattanooga) of Northern Arkansas, and their equivalents about the Ozark highlands are lowermost Mississippian rather than Upper Devonian, as previously generally correlated.

by the beginning of the Osage epoch the sea had advanced widely over the whole central Mississippi valley region, covering all of Eastern Kansas, Missouri, Iowa and parts of adjoining states. The water was unusually free from land-derived muds, as evidenced by the thick, very pure limestone deposits and the almost complete lack of clastic sediments. The limestones of the Mississippian sea have been encountered throughout most of Eastern Kansas. No highlands could well have existed along the borders of this Mississippian sea, and it is definitely known that the Ozarks were almost entirely if not completely submerged.[1]

Pennsylvanian: In late Mississippian or early Pennsylvanian time there were pronounced changes in the neighborhood of Kansas. As evidenced by the uneven surface of the Mississippian in Southeastern Kansas, Missouri and other states, the region was elevated into land and somewhat extensively eroded. In Oklahoma, as already described, there were very pronounced mountain-making movements in late Mississippian or earliest Pennsylvanian time, and it seems probable that at this time parts of Central Kansas were similarly uplifted into a range of mountains—the so-called Nemaha mountains. As soon as elevated above the sea rapid erosion began, attacking first the recently deposited Mississippian sediments, then the underlying rocks of lower Paleozoic age, and finally the granite basement. How long erosion was continued is not known, but before the Pennsylvanian sea covered the region all of the sedimentary rocks had been removed from at least the upper parts of the mountains, for in all the wells which have been reported the granite immediately underlies sediments of the Pennsylvanian. That there was a longer erosion interval just preceding Pennsylvanian sedimentation in Kansas than in many other states is suggested by the fact that the Cherokee shale is distinctly younger than the basal Pennsylvanian of those areas.

This interval of erosion in late Mississippian and early Pennsylvanian time was followed by a general depression of the

[1]Bridge, Josiah, A study of the faunas of the residual Mississippian of Phelps county (central Ozark region), Missouri: Jour. Geology, vol. XXV, pp. 558-575, 1917.

land and a consequent invasion of the Pennsylvanian sea, which reached the base of the Nemaha mountain range. It gradually rose until the low saddles were submerged, and finally covered even the highest peaks. The thick succession of sandstones, shales and limestones which border and cover the granite ridge are evidence of the long period of submergence beneath the Pennsylvanian sea.

Permian: The deposition of limestones, shales and sandstones continued without break into the Permian period in the region of the granite ridge, and we may infer the nearly continuous presence of the sea almost to the close of the Paleozoic Era.

At the close of the Paleozoic the region suffered slight but extensive orogenic movements, reaching outward from the Ozark highlands, where the upheaval was greatest. This gave the strata of Eastern Kansas a general inclination toward the northwest and developed various minor folds in the rocks. Undoubtedly the presence of a resistant mass of crystalline rock projecting far into the strata in Central Kansas caused opposing pressures here and developed folds over the ridge, and thrusting and sliding of the strata. Wright[1] has suggested such thrusting in his explanation of the structures. The movements in the overlying strata probably also affected the crystalline rocks and resulted in some of the slickensided and chloritized rocks found in portions of the basement complex.

Post-Paleozoic History.

The later history of the region is one involving minor changes of level and erosion cycles, with little evidence of later deposition in the area immediately in question. The real history of the crystalline rock area is therefore completed, so far as indicated by the data at hand.

Summary.

The existence of a large body of crystalline rock within a relatively small distance from the surface in Central Kansas is attested by numerous deep borings.

[1]Wright, Park, Granite in Kansas: Bull. Amer. Inst. Min. Eng., p. 1118, 1917.

The crystalline mass has the form of a rather narrow ridge 10 to 25 miles in width but nearly 175 miles long, trending in a northeast-southwest direction from the Nebraska State line near Bern to northern Butler County, Kansas.

The ridge appears to reach its highest elevation and to approach the surface most nearly in Nemaha County, Northern Kansas, where it is about 600 feet above sea level. Its maximum height above the surrounding crystalline floor is probably at least 2,500 feet. Some wells have been drilled apparently near the crest of the granite ridge, others some little distance down the flanks.

The material of the crystalline mass is for the most part a typical granite. Quartz prophyry and chlorite schist have also been identified.

The uniformity in texture of the granite and the entire absence of metamorphism and of pronounced structural displacements of the strata above the granite are evidence that the mass is not an intrusion into the Pennsylvanian beds.

The same facts, and the presence in the sediments of material possibly derivative from the granite, make most plausible the hypothesis that the granite is an unlifted portion of the Pre-Cambrian crystalline floor.

The age of the granite is probably Pre-Cambrian.

The time of uplift of the ridge is not definitely known, but is probably late Mississippian or early Pennsylvanian.

The ridge, which at the time of its uplift was a prominent mountain range, is here named the Nemaha mountains.

RAYMOND C. MOORE.

Discussion.

Mr1 Bloesch: I know one plaec in Kansas that may throw more light on the subject. There is a place on the Woodson-Wilson county line south of Yates Center where the sandstone is changed to quartzite with quartz veins. There was a mining ex-

citement there at one time and the locality was called Silver City. There is strong folding and doming in that part of the State. The dome was drilled, but proved to be barren. Another peculiarity at Yates Center is that the oil is heavy. All these things should be studied a little more closely and they may lead to some new explanations.

A CONTRIBUTION TO THE STRATIGRAPHY OF THE RED BEDS.

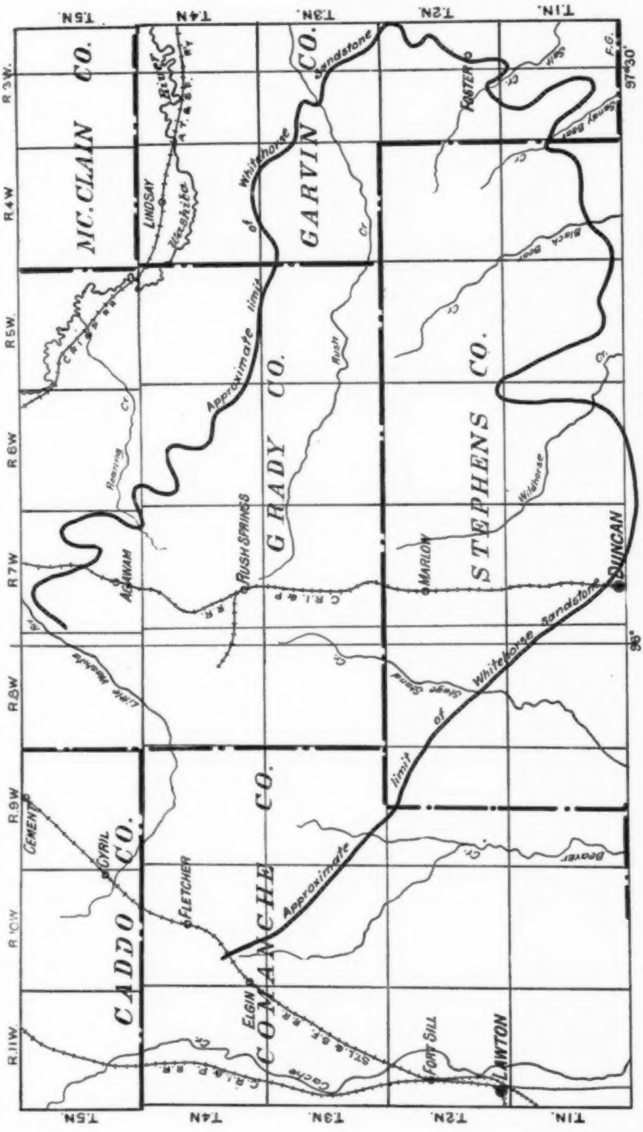
By D. W. OHERN, *Oklahoma City, Oklahoma.*

The early opinions of geologists regarding probabilities of oil and gas in the Red Beds area of Oklahoma are interesting. As late as 1912 it was considered that the eastern limit of the Red Beds area was the western dead line for oil and gas. Almost exactly six years ago (March, 1912), the Cushing field was discovered. This field is about on that dead line. The next year saw the advent of the Healdton field in the Red Beds area. Since that time the West Cushing, Ripley, Ingalls, Morrison, Billings, Garber, Walters and Cement fields have been discovered. These are all in the once condemned territory, some being in the very midst of it. Thus we have come to recast by degrees our ideas of what constitutes unpromising territory; and so complete has been the metamorphoses of ideas that we are now inclined to consider the Red Beds area, as a whole, as territory of no inconsiderable merit. A contribution to the geology of these beds, therefore, may be of value.

In 1905, Gould classified the Red Beds of Oklahoma as follows:

(Gould, Charles Newton, Geology and Water Resourses of Oklahoma; U. S. Geol. Survey, Water Supply Paper 148, p. 39, 1905.)

Quartermaster formation	
Greer formation	Mangum dolomite member Collingsworth gypsum member Cedartop gypsum member Haystack gypsum member Kiser gypsum member Chaney gypsum member
Woodward formation	Day Creek dolomite member Whitehorse sandstone member Dog Creek shales
Blaine formation	Shimer gypsum member Medicine Lodge member Ferguson member
Enid formation	



SKETCH MAP SHOWING SOUTH-EASTERN EXTENSION OF THE WHITEHORSE SANDSTONE. By D.W.Ohern.

The writer will confine this discussion chiefly to the Woodward formation as defined by Gould. The map accompanying that paper shows the formation extending southeast to the 98th meridian, the territorial boundary line. In the vicinity of Cement, Caddo County, are excellent exposures of the Whitehorse sandstone member. The Keechi Hills are composed of it almost wholly. Some of the hills east of the village are capped by dolomite, presumably the Day Creek.

The present writer has traced the sandstone from Cement southeast across southern Grady County, its northeast edge crossing the Chicago, Rock Island & Pacific Railway in the vicinity of Agawam. (See accompanying map.) Thence the sandstone continues southeast, with subdued escarpment, across northeast Stephens County and into western Garvin County. In Twp. 3 N., R. 3 W., the escarpment becomes very conspicuous, rising 150 feet to 200 feet above the surrounding country. Thence it follows an irregular southerly direction for about 15 miles, where it unites with that mapped by Wegemann, who says that "the group as a whole covers a broad area and has been traced for about 60 miles from a point north of Foster," Wegemann further shows this sandstone to extend northwest from Duncan to a point "six miles northeast of the Lawton field[1]."

There is another and more direct method of establishing the identity of the sandstone at Cement and that mapped by Wegemann. From a point three miles west of Cement southwest past Cyril, to Fletcher, one may find good exposures of the gypsum beds of Gould's Greer formation lying directly on the Whitehorse sandstone. The gypsum beds along their southwest limit do not dip beneath other beds but have been removed by erosion in that direction, leaving wide areas of Whitehorse sandstone exposed south and southwest to the escarpment mapped by Wegemann. Some five miles east of Cyril all of the Greer Gypsums have been removed and the Whitehorse sandstone area is continuous from Cement south to Wegemann's escarpment.

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[1]Wegemann, Carroll H. The Duncan Gas Field; U. S. Geol. Survey, Bull. 621-D, 1915.

[1]Wegemann, Carroll H. The Lawton Oil and Gas Field; U. S. Geol. Survey, Bull. 621-G, 1915.

The sandstone is 190 feet thick at Cement. It is deeply disintegrated in the vicinity of Agawam and Rush Springs in southern Grady County, where loose sands are a great vexation to travelers. Farther to the southeast the disintegration is not so marked, the more resistant layers giving rise to the rugged topography of northeast Stephens and western Garvin Counties.

The identity of the Woodward sandstone and that mapped and discussed by Wegemann being thus established, it follows that the beds outcropping around the southeast extension of the Whitehorse area as above delineated are probably the time equivalent of Gould's Blaine formation. Indeed from a point four miles east of Cement southeast to the Chicago, Rock Island & Pacific Railway one may find isolated outcrops of gypsum, presumably of one bed. This bed is probably a fading remnant of one of the beds of gypsum of which the Blaine formation is largely composed farther northwest. Besides this one bed, however, one may find little in the beds subjacent to the Whitehorse to suggest the Blaine formation as typically developed.

It further follows from the above correlation that a part of the beds mapped by Gould as surrounding the Wichita Mountains and described as "Red Beds of uncertain relation" are probably also the equivalent of the Blaine.

If the Whitehorse sandstone area is surrounded to the southeast by one of the Blaine formations or its equivalent, it is but a step further to say that the Blaine area is in turn surrounded by one of Enid age. Indeed, a study of the area surrounding the Whitehorse sandstone on the northeast, southeast and southwest, supplemented by data furnished by well logs, suggests that the Enid formation or its equivalent in part lies unconformably on strata of higher antiquity along the north side of the Arbuckle-Wichita uplift.

A CONTRIBUTION TO THE GEOLOGY OF EASTERN OSAGE COUNTY.

By F. C. GREENE, *Bartlesville, Oklahoma.*

The following paper is a brief summary of the geology of the eastern portion of Osage County based on a study of the outcrops in a number of townships and a fairly representative collection of well logs. The beds involved have a thickness of approximately 2,300 feet in the latitude of Pawhuska, but thin to the north and thicken to the south. The correlation of these formations with those of Kansas will not be attempted except in a few instances.

The Bartlesville sand appears to be the lowest Pennsylvanian bed that can be recognized with certainty over a large area, though in some well logs the Tucker and Burgess sands are reported in the interval between the base of the Bartlesville and the top of the Mississippian. Judging by the rapid changes in the thickness of these beds and the intervals between them, these sands are discontinuous lenses that may or may not lie at the same horizon.

The Bartlesville sand ranges from a few to 150 feet or more in thickness. It lies at an average distance of 400 feet below the top of the Fort Scott limestone or "Oswego lime" of the drillers. In some places in the northeastern corner of the county only a few feet of shale intervene between its base and the top of the Mississippian, but the interval increases to the south, and in T. 20 N., R. 12 E., it is about 200 feet. In T. 26 N., R. 9 E., the Mississippian is within 200 feet of the base of the "Oswego" and there, as well as in some of the adjoining townships, the Bartlesville sand was probably not deposited.

In Vernon and Barton Counties, Missouri, a sandstone known locally as the Clear Creek has a thickness of 80 to 130 feet and lies about uniformly 45 feet above the Mississippian and about 225 feet below the Fort Scott limestone. It is, in all probability,

the northeastern extension of the Bartlesville. It contains many oil seepages which have caused several dry holes to be drilled in that region into the Ordovician, Cambrian and even into the pre-Cambrian.

The first important limestone above the Bartlesville sand is the "Pink lime" of the drillers. Its usual thickness is 3 to 15 feet and it lies 215 feet above the top of the Bartlesville in the northeastern part of Osage County and 100 to 150 feet above the latter in T. 20 N.; that is, the interval decreases southward, a notable exception to the general rule. The interval from the "Pink lime" to the base of the "Oswego" or Fort Scott increases from 100 feet to over 300 feet from north to south. These compensating changes in interval cause the larger interval—that between the top of the "Oswego" and the top of the Bartlesville—to remain fairly constant at 350 to 450 feet.

The "Pink lime" is one of the most persistent beds encountered in drilling and the writer believes it to be continuous with a bed of equal persistence in Southeastern Kansas and Southwestern Missouri, where it lies about 80 feet below the Fort Scott limestone. Incidentally it may be stated that this bed has been traced northward across Missouri into Iowa.

Several oil sands occur between the "Oswego" and "Pink limes" but the writer has not made a study of them as yet. The Peru sand of the Cleveland field is one of them and is obviously a misnomer, as the true Peru sand lies above the "Oswego."

The average thickness of the Fort Scott limestone or "Oswego" is perhaps about 75 feet, but it is reported 30 to 100 feet, depending on how many of the thin limestones immediately above or below it the driller includes in the "Oswego." The "Oswego" has been studied in detail along its outcrop and will not be discussed further here.

The Labette shale, lying between the "Oswego" and the "Big limes" and including the Peru sand, is about 125 feet thick in the northeast corner of Osage County. Its thickness is fairly uniform to the south but it seemingly thins slightly to the west and more so to the southwest, and, in the region around Cleveland, little or no shale is reported at its horizon. Rather great

differences in thickness are reported in wells only a short distance apart. The most logical explanation of this, as well as of the absence of this shale in the Cleveland pool, lies in the presence of limestone lenses in the Labette shale that are included by the driller with the "Oswego" or "Big limes."

The "Big lime" exhibits little uniformity in thickness as reported by the drillers. It ranges from 15 to 160 feet, possibly averaging about 75 feet. In any one locality the total thickness of the "Oswego" and "Big limes" and the intervening beds is usually fairly constant.

As already mentioned, little or no shale is reported at the horizon of the Labette shale in the Cleveland pool, but a thickness of 150 to 160 feet of limestone is recorded and called either the "Big lime" or the "Oswego". The writer believes it to be a combination of the two, as the distance from the base of the limestone in question to the "Pink lime" below and from the top to the Lenapah limestone above is approximately the same as at nearby points to the north and east where the "Big" and "Oswego limes" are differentiated.

The next persistent limestone above the "Big lime" is the "Checkerboard" or "Little lime" of the drillers. It is reported 5 to 30 feet thick, increasing to the north. In the northern townships it is 100 feet or less above the "Big lime" but in T. 20 N. it is 250 to 400 feet above the "Big lime". This interval is chiefly shale in the northern part of the county, but to the south contains considerable sand. The Cleveland sand, in the Cleveland pool, occupies locally 160 feet of this interval. Around Hominy it appears to split into two beds, either of which may be termed by the drillers the Cleveland sand. The Cleveland sand is thinly represented as far northeast as T. 23 N., R. 11 E.

Above the "Little lime" is 275 to 450 feet of shale and sandstone, extending to the Lost City or Hogshooter limestone. The minimum figure is in the northeastern townships, where the interval is chiefly shale, and the maximum is in the region between Cleveland and Hominy. A thin sand near the top of this interval is present near Bartlesville, where it is sometimes termed the 700-foot sand. This sand thickens to the southwest and is the Layton sand of the Cleveland pool. It is here 10 to 70 feet thick and lies about 200 feet above the "Little lime".

The Lost City limestone is a prominent ledge along the Arkansas River, but is very thin in the northern part of T. 20 N., R. 12 E. The writer has not traced it into the Hogshooter but the relation of the Lost City and Hogshooter to the beds above and below seem to indicate strongly their continuity.

The Dewey limestone lies 135 to 175 feet above the Lost City in R. 12 E., but in the region of Hominy the interval appears to be slightly less. The Dewey limestone extends at least to the Arkansas River. Between these limestones is a sand of irregular thickness that is also called the Layton by some drillers. It is approximately 200 feet above the lower Layton.

At a distance of 60 to 130 feet above the Dewey limestone is the Avant, which helps to form one of the most prominent escarpments of the area. Near its type locality, where it is known to drillers as the "Oil City lime", it has a thickness up to 45 feet but decreases to the south as well as to the north.

A series of limestones, three in number, outcrop in the hills west of Avant but become thin in the southern part of T. 23 N., R. 11 E. These limestones are approximately 180 feet above the Avant limestone, and are enclosed in thick sandstones. One of them, or possibly all three, is probably the Stanton of Ohern. In the Cleveland and Hominy pools a sandstone about 100 feet thick, the Peoples sand of the drillers, is found 200 to 300 feet above the upper of the Layton sands. This is believed to be a combination of the enclosing sands of the Stanton limestone. It is about 500 feet above the Layton sand of the Cleveland pool.

The Bull Creek limestone, which is well exposed on Bull Creek, in the northwestern part of T. 23 N., R. 11 E., is the next succeeding persistent bed. It is 5 to 15 feet in thickness and lies about 100 feet above the Peoples sand and 150 feet above the Stanton limestone. The characteristics of the Bull Creek limestone, north of Bigheart, are not known to the writer. To the southwest it may be identified in most of the logs of wells in the vicinity of Hominy.

Above the Bull Creek limestone is an interval of irregular shales and sandstones 80 to 125 feet in thickness, overlain by the Wild Horse limestone. The most conspicuous outcrop of this bed is in the western half of T. 22 N., R. 10 E., and it forms a

good marker in well logs around Hominy, where it is 5 to 40 feet in thickness. North of T. 23 N. the Wild Horse limestone is either very thin or absent, although its position is indicated by a massive sandstone which is believed to be that exposed at Quapaw. In many places the base of this sand is extremely coarse, containing pebbles up to one-fourth inch in diameter.

The section above the Quapaw sandstone contains no well-marked beds for about 200 feet but many of the sandstones may be traced across a township. At about 220 feet above the Wild Horse limestone is the Rock Creek limestone, well developed in T. 26 N., R. 10 E., but very thin in the southwest corner of the next township south.

The Rock Creek limestone is probably about 325 feet below the top of the Elgin sandstone. The lower 150 feet of this interval is chiefly sandstone interbedded with red shale. Above this is the thick shale bed that forms, with the Elgin sandstone, the prominent escarpment that stretches from Cleveland to the Kansas line.

In the Cleveland pool the top of the Elgin sandstone is about 550 feet above the Wild Horse limestone, 775 above the Peoples sand, 1,315 above the Layton sand, 1,510 above the "Little lime", 1,855 above the "Big lime", and 2,300 feet above the Bartlesville sand.

Tulsa, Oklahoma, February 13, 1918.

Discussion.

Mr. Ohern: I understood Mr. Green to say that the Lenapah limestone is the equivalent of the "Checkerboard." I used to think so and I am sorry to say that I am in print to that effect. But such is not the case. The Lenapah limestone is the one that caps the hill in the western part of the city of Nowata. But it does not extend south beyond that point. It is replaced by the Dawson coal. The "Checkerboard" limestone lies to the west and about 70 feet above the Lenapah-Dawson horizon.

There is one limestone omitted in the discussion—the Altamont. In the Kansas section the Pawnee limestone is succeeded

by the Bandera shale and this in turn by the Altamont limestone, which has a thickness of 40 feet. Although the Bandera shale has a thickness of 125 feet at the State line, it thins rapidly southward and disappears from the section just east of Talala, the Altamont and Pawnee limestones being thus brought together, forming the Oolagah limestone or "Big lime" of the drillers. The term "Big lime" is doubtless used in the northern part of the State as applying to either the Altamont (lower Parsons) or the Pawnee, and such usage has given rise to much confusion.

Mr. Berger: I have a few words to add to Mr. Green's paper. In the south end of T. 22 N., R. 10 E., you will find four and five and sometimes six limestones below the Big lime and it is often hard to tell which of these limes is the Oswego. The Big lime thins from 100 feet in T. 23 N., R. 11 E., to 15-25 feet in the Cleveland pool. The Oswego is present in the Cleveland pool, but has a much less amount of shale between it and the Big lime than regularly expected in the other parts of Osage County. This thickness varies from 30 to 45 feet. Mr. Green also spoke of the Pink lime. It is my belief that this name applies to any lime that the driller happens to strike below the Oswego. I find sometimes as many as six limestones below the Oswego lime. In numerous cases I find three to four limestones. In many cases the color of the pink lime is given as white, so the color can not always be given as a determining factor for recognizing the Pink lime. I have decided that what is considered the Bartlesville sand in Osage and Washington Counties is not the same sand throughout. Any producing sand that the driller may touch from 200 feet to 600 feet below the Ft. Scott lime is called the Bartlesville.

VALUE OF OIL GEOLOGY IN THE MID-CONTINENT FIELD.

By Edward Bloesch, *Okmulgee, Oklahoma.*

The value of geology to the oil business is still questionable in the minds of many oil producers. In many cases they overestimate or underestimate its value. This attitude of the oil producer, and in some cases others, toward geology is due largely to the fact that they either do not employ trained and dependable geologists or do not utilize the information furnished them.

The geologist can keep the producer out of territory where there is no chance of production at all, as areas of igneous rocks, and in possible territory he can keep him out of the least likely places, as synclines, thus saving him the expense of drilling dry holes. The geologist's services are also very valuable in developing proven territory and he ought to be consulted for this purpose. Generally, however, he is called on to locate new pools.

The oil in the Mid-Continent field is associated with water and consequently accumulates in the high places, where it is hedged in either by reverse dips or by lensing of the sand. The pools accumulated on account of structure can be located from the surface conditions, but it takes the drill to find the ones due entirely to sand conditions. The numerical proportion between the two kinds of pools is a criterion for the value of oil geology.

Having personal knowledge of practically all the oil pools in Oklahoma between the Arkansas River in the north and the Arbuckle-Wichita Mountains in the south, and considering this territory as representative for the entire Mid-Continent field, the writer compiled some time ago statistics on this area. Since then new pools have been opened and old ones have been connected up. On account of this no list of the pools is given, but only the results. They are based on surface observations in order to approximate conditions confronting the geologist in virgin territory.

From the oil and gas pools of the region outlined above about 50% are located on anticlines, about 25% on terraces and the others are due to sand conditions with one pool accumulated by a fault.

By using the list of pools given by the Oklahoma Geological Survey on the map of its oil report*, where in some places different small pools are considered as only one, the percentage is still more in favor of the structural pools.

From the 65 areas of oil and gas development listed on this map in our territory there are located:

On anticlines	35	or	54%
On terraces	16	or	25%
Accumulation due to faults	2	or	3%
Accumulation due to sand conditions	6	or	9%
Cause of accumulation unknown	6	or	9%
Total	65	or	100%

In this table the faults show up more than they ought, as this includes Paden, which has up to the present only a single well.

The following table contains all the pools of Oklahoma according to the above named map. The computation is less reliable, as there is a considerable percentage unknown and the other pools have not all been studied by the writer in person, who had to rely on information from various sources.

Anticlines	67	or	58%
Terraces	20	or	17%
Faults	2	or	2%
Sand lenses	8	or	7%
Unknown	18	or	16%
Producing areas of Oklahoma	115	or	100%

The only publication on this subject is by Dorsey Hager*. He does not try to include all the pools of a certain territory, but

*C. W. Shannon: Okla. Geol. Surv. Bull. 19, part 2, plate 4, fig. 2a.

tabulates the main oil fields of Oklahoma and a few of Kansas. His results are: 67% on anticlines, 27% on terraces and 5% on sand lenses.

The results gained on a different basis match fairly well. It is evident that as soon as the small pools are eliminated the percentage of accumulation on account of sand conditions decreases. This means that the accumulation of most of the important pools is due to structure.

More detailed investigation of the pools studied by the writer will probably reduce the number of producing terraces in favor of the other two kinds of accumulation. In some places, where a hurried examination showed only levelling up of the strata to a terrace, close investigation may reveal a reverse dip. On the other hand lensing of the sands may by chance take place, where there is a terrace and would really be the cause for the accumulation. While the above statement considers only the surface structure, it is more than likely that a good number of pools located apparently on terraces and even on a normal dip, are in reality accumulated on anticlines, which, on account of unconformities, do not show at the surface.

Even where the accumulation of the oil is due to lensing of the sand, it is not without relation to structure. Most of these pools occur where there is a change in the direction of the strike, that is, on noses or plunging anticlines, whose axes pitch in the direction of the general dip. This means that even in territory where regular domes and anticlines are absent a test located by a geologist has a better chance than one located at random. After a certain amount of drilling has been done in a locality the geologist can by careful study and correlation of the well logs figure out areas, where certain sands pinch out, and where this lensing of the sand may take the place of a reverse dip in accumulating oil or gas. This effort, however, is often made futile by the fact that as a rule the available well records are incomplete and inaccurate. It is safe to say that the operators of the Mid-Con-

*Dorsey Hager: The Evidence of the Oklahoma Oil Fields on the Anticlinal Theory. Bull. No. 122, Feb., 1917, American Institute of Mining Engineers.

tinent field lost millions of dollars in not keeping accurate records of their drilling operations.

The territory between the Arkansas River and the Arbuckle Mountains was considered typical for the Mid-Continent field, because it contains the country from the Glen Pool south and east, where the sands are very inconsistent and consequently have a good deal to do with the accumulation of oil and gas, and also the territory from the Cushing field to the northwest, which contains some of our biggest producing anticlines. A few remarks on the other parts of the Mid-Continent field may not be out of place. In Osage County most of the production is closely related to the structure, being located on pronounced domes and anticlines. In the territory of the Cherokee Nation some of the pools are located on well developed anticlines, but lensing of the sands is also in evidence. In the Eastern Kansas field a number of anticlines are producing, but sand conditions seem to be the dominating factor. Some good-sized anticlines produce gas on top and the oil occurs so far down the dip as to give the impression that some of the sands may only partly be saturated with water. Further west in Kansas structure is again leading in accumulation. The production in the big Eldorado Augusta field, for instance, follows the structure closer than in any other big pool of the Mid-Continent field. The oil and gas fields west of Ardmore and over to the Wichita Mountains are anticlinal[1]. The same is true of the big fields around Wichita Falls, Texas[2]. Farther south in the Pennsylvanian area of Texas the pools are located on slight domes and terraces and sand irregularities may possibly play an important part in the acccumulation. The anticlinal gas production near Ft. Smith, Ark., completes the list.[3]

From the facts mentioned above it can be estimated that

[1]C. H. Wegemann; U. S. Geol. Survey Bull. 621.

[2]J. A. Udden: A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties, Tex. Bull. University of Texas, Number 246, 1912. E. W. Shaw: Gas in the area north and west of Ft. Worth, U. S. Geol. Survey Bull. 629.

[3]C. D. Smith: Structure of the Fort Smith-Poteau gas field, Arkansas-Oklahoma. U. S. Geol. Survey Bull. 541-B.

from the oil and gas pools so far discovered in the Mid-Continent field at least three-fourths could have been located by the geologist using surface indications only and quite a number more if he had been supplied with complete and accurate records of previously drilled wells and dry holes.

This ratio of three to one, however, does not show the full value of geological work. While the pools accumulated on account of sand conditions are generally one sand pools, the ones located on anticlines have usually, at least in deep sand territory, several producing horizons. The Cushing field, for instance, produces from five different sands, not counting some stray sands and deep ones, that have not yet been tested. Counting both oil and gas sands, the recently opened Garber Pool has already the same number of producing horizons and the sands producing in the Cushing field have not yet been touched.

The fact that a test has been located by a geologist on an anticline does by no means insure success. The sands may not be present or they may be too thin or not porous enough to produce oil in commercial quantities.

The term "commercial quantity" is variable with time and location. It also depends on the quality of the product and the expense involved in reducing it to possession and bringing it to market.

In some parts of Kansas a gas well of 100,000 cubic feet capacity is worth saving, while in some parts of Oklahoma a well of ten million cubic feet would rather be a liability than an asset. Some gas (400 and 1,000 foot sands at Dexter, Kans.) contain so much nitrogen as to make it almost worthless. As far as oil is concerned there is now such a big demand that any grade can be produced profitably even at a great distance from the market, if it is present in fair quantities and at a reasonable depth.

The size of a paying well depends largely on the market. When oil was 40 and 50 cents a barrel, wells with an initial production of ten barrels were plugged as dry holes even in the shallow field. Now such wells are considered good paying propositions at least to a depth of 1,500 feet. It may be stated that

the size of a well depends more on the thickness and porosity of the sands, gas and water pressure than on the structure.

There is not enough material available to estimate the percentage of anticlines which failed to produce in the Mid-Continent field, but their number is thought to be small. There is no instance known to the writer in this field where a fair sized closed anticline has not shown some oil or gas if properly tested, but in a few instances it was not in commercial quantities. Some big anticlines showed good gas in places too far from the market. The anticline at Dexter, Kansas, ranging among the biggest ones in the field, has so far furnished only one decent producer, and this oil well was not considered a paying proposition at the time of its completion on account of the low prevailing market.

Sometimes good anticlines are given up after a first unsuccessful test. How much testing it may take to locate the oil on an anticline can be seen from the following observation: There is a small anticline east of Lenapah, on which there were three dry holes. Later an oil well was completed and drilling machines were busy extending the producing area.

The first test on an anticline ought to be drilled on the highest point. If unsuccessful this one hole can only be considered a fair test of the anticline, if all the expected sands showed water, If some of the sands expected in this territory were missed or happened to be dry or had gas or a showing of oil without water, additional tests ought to be drilled along the axis of the anticline, particularly on secondary domes and eventually down the dip, preferably on the longer limb of the anticline and on adjoining terraces. In order to be quite sure that nothing has been overlooked it would be necessary to locate the water level in every sand and drill practically every location on the anticline above this water level. For business purposes this procedure is too expensive, but the only man that is competent to decide how far this program should be followed, that is, when an anticline has had a fair test, is a geologist acquainted with that particular part of the field.

Test wells on anticlines always ought to be prepared to go to the deepest horizon known to produce oil or gas in commercial quantities, providing this horizon is not so deep, that average

size wells would not pay. The geologist can figure from the surface strata at the location the approximate depth at which the different sands ought to be encountered, but he can do this much more accurately after he has been furnished a detailed log of the upper part of the hole. Scores of wells have been abandoned only a short distance from a sand, because the operator did not know it or listened to an incompetent driller or interested contractor.

Vast sums paid out for leases and for drilling dry holes could have been saved if geology had been applied in the Mid-Continent field from the start. At that time it was easy to locate a first-class proposition with a very strong chance for big results. This has changed. Outside of Osage County there are very few first-class propositions left in the Mid-Continent field. In order to locate new pools we have to test second rate propositions like small anticlines, terraces, faulted areas, anticlines outside of the oil belt, places where the outcrops are not sufficient to figure out the structure with accuracy, very shallow territory where there is only a possibility for one or two sands, very deep territory with a considerable overburden of probably barren formations (Red Beds), places where the deep sands are cut out by granite, territory where unconformities make the structure of the oil-bearing formations differ considerably from the surface structure, or eventually older formations not yet known to produce oil in the Mid-Continent field.

Some operators may think that if the geologist can not locate for them places where they have a 90% chance they may just as well do without him. Of course, the old-fashioned wildcatters will open a few pools that would not have been found by the geologists, just as they did in the past. They will find out through experience, however, that with the chances of locating new pools diminishing, they can less and less get along without geological advice. They will not only need geologists, but geologists of considerable experience, and they will have to consult them not only for locating anticlines, but in the various phases of their drilling operations.

The scientific end of the oil business needs closer attention and there ought to be a better co-operation between producer and geologist.

Edward Bloesch.

Discussion.

Mr. White: In connection with suggestions that Mr. Bloesch made for deep drilling I could add that West Virginia has now the deepest drilled hole in the world, near the city of Clarksburg. Previously a well known as the Czuchow was drilled to a depth of 7,349 feet, but week before last this well in West Virginia went to 7,353 feet, and they expected to begin drilling again day before yesterday unless the Government geologist who was there yesterday to finish the temperature records should cause delay. You will be interested in knowing that at a depth of 7,310 feet the thermometer registered a temperature of 158.8 degrees Fahrenheit. This temperature shows not so great as in the Czuchow well in Germany, where at 7,287 feet a temperature of 182 degrees was reported, but the method used was unreliable and liable to serious error.

Mr. Deusson: Do they have any sandstone in the lower portion of the well?

Mr. White: They expect to find the Oriskany Sand at about 7,400 feet. They have already developed a new source of gas in the Benson Sand that seems to correspond with the Bradford Sand of Pennsylvania. They get this sand at 4,350 feet below the Pittsburgh Coal. The wells are not large. They vary from one-half to one million feet, but the rock pressure is 1,800 pounds to the square inch. No water has been found below a depth of 2,000 feet, but no porous sands have been encountered in the last 5,000 feet, the rock material being mostly shales and slates of the Upper Devonian.

Mr. Deusson: Dr. White, what do you consider the cause of no oil or water production?

Mr. White: Because there was no porous rock. There was plenty of porous rock below 6,000 feet in the Geary well in Washington County, Pennsylvania, and large quantities of salt water and some gas were found at 6,250 feet in the Oriskany Sand, and

again at 6,550 feet in a porous limestone. In this Geary well they got the first water in the sandstone at 6,250 feet and then 300 feet under that they got it in limestone, showing that neither of these porous rocks had been crushed by the weight of the superincumbent strata at these great depths.

THE GEOLOGY OF CUBAN PETROLEUM DEPOSITS.

By E. DeGolyer, *New York City, New York.*

I. Introduction.

The earliest known discovery and use by white men in the New World of any member of the petroleum family is probably that made by Sebastian Ocampo in the Bay of Havana, Cuba, in 1508. Ocampo found on the waters of the bay a "liquid bitumen" with which he careened his ships and as a result of this circumstance called the bay "Puerto de Carenas", a name which it bore until 1519, when the city of Havana was moved form its original foundation on the south shores of the island to its present site and the name of the bay changed in conformity.

Oviedo, in 1535, mentions a spring of "pitch" near the coast in the province of Puerto Principe and another on the shores of Havana Bay. The asphalts, whose occurrence in Cuba is widespread, were probably well known during colonial times and petroleum itself was not unknown during that time, since Humboldt, who visited the island during the early part of the last century, mentions the occurrence of petroleum springs in the serpentines of Cerro de Guanaboca (sic.) and the reported occurrence of petroleum springs in the eastern part of the island. The baths of Santa Rita in Guanabacoa, famous during the colonial epoch, consist of springs of medicinal waters coming from crevices in the serpentine. The most medicinal of these springs seems to be the one accompanied by exudations of a petroleum of fairly good quality.

La Sagra published, in 1828, an extended account of the asphalt deposits near Havana. Navarro published, in 1829, an account of various bituminous deposits, and in 1837 R. C. Taylor

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[1]The references in this paragraph are taken from T. Wayland Vaughan's "Bitumen in Cuba,,' p. 344, Eng. & Min. Jour., Mar. 8, 1902.

described certain asphalt deposits near Havana as coal. In 1857, Moisant published a *"Memoria sobre los Productos Bitumenosas"*.[1]

The various asphalt deposits were worked extensively during the latter half of the last century, but, with the increase in production of asphaltic residuums by oil refineries during the present century, the mines have been abandoned until not a single one is being extensively worked at present, and Cuba imports rather than exports asphalt.

During 1880 an enterprising Spaniard, one Manuel Cueto, who had observed gas escapes in the Motembo vicinity, commenced drilling a well at that place, and on August 18, 1881, he succeeded in striking a deposit of natural naphtha.

From 1890-96, Alvarez and associates drilled several wells in the Lagunillas district west of Cardenas and succeeded in developing a well which is said to have produced 100,000 gallons of oil.

In 1901, a report on a geological reconnaissance of Cuba was made by Hayes, Vaughan and Spencer. The various mineral resources of the island, including asphalt and petroleum occurrences, were visited, previous literature reviewed insofar as possible, and the occurrences described.[2] H. E. Peckham in the same year described various oil and asphalt occurrences in the vicinity of Cardenas.[3]

On December 5, 1913, a considerable flow of gas was encountered in a well being drilled for water on the grounds of the Tropical Brewing Company at Puentes Grandes, a western suburb of Havana.

During the latter part of 1915 the discovery well of the Union Oil Company, at Bacuranao, was brought in.

Recent complete reviews of oil operations in the island have

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[2]Hayes, C. Willard, T. Wayland Vaughan, and Arthur C. Spencer—Report on a Geological Reconnaissance of Cuba, made under the direction of General Leonard Wood, Military Governor, 123 pp., 17 figures and maps, Washington, 1901. Chapter on asphalt and petroleum same as Vaughan's work already cited.

[3]Amer. Jour. Sci., 4th series, pp. 33-41, 1901.

been made by F. K. Gillespie[4] and an anonymous writer[5] who is well acquainted with his subject.

Wells resulting in appreciable flows of oil or gas have been drilled at five points on the island, in order of their discovery as follows: Montembo on boundary between Matanzas and Santa Clara, the Alvarez or Felicidad properties some 6-7 miles west of Cardenas, the Shaler Williams property at Guayabal, some 25 miles west of Havana; at Puentes Grandes, a western suburb of Havana, and at Bacuranao, near Minas, some 10 miles east of Havana.

Small amounts of gas are produced from the Motembo and Shaler Williams wells and approximately 150 barrels per day of oil of good quality is being produced at the Bacuranao properties. This constitutes the commercial production of Cuba at the present time.

A number of unsuccessful wells have been drilled at various points on the island. These operations will be reviewed in greater detail at another place in this paper. Interest in the oil possibilities of the island seems to be greater at present than at any previous time and several of the larger American companies are either investigating properties or carrying on actual operations.

Oil rights pertain to the Government, as in most Spanish-American countries, and are secured by denouncements or filing on claims according to regulations set forth in the Mining Code. Denouncement may be made by any person or legal corporation, native or foreign, and subsoil titles are perpetual and transferrable quite the same as are surface titles. The cost of completing denouncement, including fees, taxes, official survey, etc., in blocks of 1,000 hectares, is approximately $3.75 per hectare (2.471 acres) and the time required to complete title, according to past practice,

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[4]The real facts as to the Cuban petroleum situation, Oil, Paint, and Drug Reporter, Issues for July 2, 9, 16, 23 and 30, 1917.

[5]Cuba attracting attention of big oil operators, Oil Trade Journal, vol. 8, No. 6, pp. 56-61, June, 1917.

is about 12 to 14 months.[6] The greater part of the province of Havana, where excitement centers at the present time, is already under denouncement.

The author visited oil prospects on this island in 1913 and 1914, and in 1915 spent several months mapping the geology of certain areas in Havana and Pinar del Rio provinces and visiting various oil indications. Acknowledgment is due and is gratefully rendered to Messrs. E. B. Hopkins, Ben C. Belt, Victor E. Gothe, and numerous others for information furnished. The author further acknowledges with thanks, the permission of J. B. Body, Esq., to make public certain information contained in the present paper.

II. Geology.

Generally the geology of Western Cuba is well exposed, but parts of it are so complicated that its exact expression would require the most detailed mapping. For the purpose of this brief paper, however, the main structural and stratagraphic features may be described as follows:

There are five great groups of rocks which make up the eastern half of the island and which are, for the most part, structural, if not stratagraphic, units. The oldest rocks are apparently the schists, slates, limestones, granites, etc., which have been termed the basal complex[7]. They are of unknown age, possibly including Paleozoic rocks, and with them, for convenience in maintaining the structural grouping, are included the serpentines which are probably of Cretaceous age. The second group consists of an enormous thickness of Jurassic limestones and the third group of various Cretaceous formations consists of marls, shales, sandstone, grits, conglomerates, arkoses, and limestones, generally severely faulted and folded and greatly metamorphosed in certain localities.

The preceding groups are generally closely folded and are

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[6]The various mining laws have recently been compiled and published under the title, "Disposiciones Vigentes para la Adquisicion de la Propriedad Minera y la Explotacion de sus Riquezas", Habana, Rambla Bouza y Cia., 1915. This edition is official.

[7]Hayes et al., Op. cit , p. 20.

overlain unconformably by the third group consisting of various Tertiary formations, for the most part limestones, showing comparatively low dips wherever observed. The fourth group consists of igneous rocks younger than the serpentines and perhaps including Tertiary intrusives. The fifth group includes coral limestones of Quaternary to recent age, terrace gravels, soils, beach sands, and alluvial deposits of recent age. They are of little or no importance in consideration of the petroleum geology but are included to complete the section.

Stratigraphy.

Basal Complex or Protaxis of the Island.

The oldest rocks in the island, and the basement upon which the succeeding geological formations were laid down, consists of highly metamorphosed rocks; schists, slates, limestones, and marbles. They outcrop in a large area in the southern part of the province of Santa Clara and the formation is reported to include granites near the south end of the harbor of Santiago de Cuba, near the eastern end of the island, and south of Santa Clara[8]. The Santa Clara granite is apparently the source of the 300 feet of granite arkose encountered in Menendez Well No. 1 of the Cuban Oil Company.

Outcrops of this formation are not known west of the longitude of Cienfuegos, but small patches are doubtless included with the serpentines and more recent igneous rocks which outcrop over wide areas to the westward.

Into the older rocks, as well as the Cretaceous and Jurassic rocks, have been intruded, at several different periods, various igneous rocks, for the most part basic, which have subsequently been largely altered into serpentine.

The serpentines outcrop in every province of the island, the westernmost exposures known to the author being southwest of San Cayetano in the province of Pinar del Rio. Other serpentine masses outcrop along the axis of the island, on the northern flank of the Sierras Rosario and Organos in Pinar del Rio; west of Bahia Honda, where the Moralillo well of the Cuban Petroleum Company, Ltd., is reported to have encountered serpentine at 30

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[8]Hayes et al., Op. cit., p. 20.

feet and continued in it to 1,811 feet, at which point the well was abandoned; near Martin Mesa and Boyer, north of Guanajay; at Puentas Grandes, west of Havana, where it was encountered at depths of about 60 feet in wells drilled on the grounds of La Tropical Brewing Company; in a large area extending from the east side of Havana Bay at Regla to a point about midway between Campo Florida and Jaruco; intermittently along this same line to Matanzas; at a point south of Colisco; in the Tetas de Camarioca, west of Cardenas; at Sabanilla de la Palma; Motembo, and over wide areas in Santa Claus, Camaguey, near Holguin, and eastward.

The various wells of the Union Oil Company at Bacuranoa were drilled into serpentine and a nearby well, that of A. C. Landes, et al., was drilled to a depth of 1,232 feet, reporting serpentine throughout. The various wells drilled by the Cuban Oil Company, west of Cardenas, encountered serpentine at depths of 790, 1,040 and 1,835 feet respectively, and the wells of Manuel Cueto and the Cuban American Oil Company, at Motembo, were drilled in a serpentine area which had been subjected to later intrusions. Wells were also drilled in serpentine to depths of 1,392 and 743 feet respectively, by the Cuban Petroleum Company, Ltd., at Anton Diaz, some four miles west of Santa Clara.

It should be noted that all oil which has yet been produced in Cuba, with the exception of the Shaler Williams well, has come from "sands" at the contact between the serpentine and the overlying sedimentary rock or from the serpentine.

It is also worthy of attention that most of the asphalt deposits and oil seepages occur in areas of serpentine. Along the contact of the serpentine and sedimentary outcrops, but well within the serpentine area, one often finds lenses or patches of limestones impregnated with oil or oil residue. This limestone is similar to the Cretaceous and Jurassic limestones and was evidently caught up at the time of intrusion by the igneous rock from which the serpentine was derived[9]. Since the arkose and conglomerates of the basal Cretaceous in Santa Clara contain serpentine pebbles, there would seem to be serpentines of several distinct ages.

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[9]This was shown to me at the Felecidad denouncements near Cardenas by the late Dr. C. Willard Hayes.

The serpentines have been intruded in turn by various igneous rocks. A dyke of diorite (?) cutting the serpentines in the outcrop east of Havana is well exposed by a quarry between Regla and Guanabacoa. Along the walls of the dyke and through crevices in it considerable oil seeps to the surface.

Jurassic.

Vinales Limestones.

The axial portion of the Sierra Rosario and Sierra Organos, in the province of Pinar del Rio, is a thick massive limestone of Jurassic age[10]. This limestone is hard, blue, and cut by a fine network of thin calcite veins. It is quite soluble and cavernous and under proper conditions would probably form an excellent reservoir for oil.

From a rapid examination of the section between Pinar del Rio and La Experanza, it is estimated that at least 2,500 feet of limestone are exposed and the base of the formation is not seen.

This formation is believed to have been encountered in the Menendez well of the Cuban Oil Company, near Itabo, Matanzas province, which entered it at a depth of 350 feet and was still in it at 2385 feet when the well was abandoned. It has been suggested that the great thickness of limestone shown in this well is the result of drilling into a steeply dipping Cretaceous limestone such as outcrops in the vicinity of Coralilla, to the southeast of the property. The author does not believe such to have been the case. No fossils were found but the formation was lithologically identical with the Vinales limestone from known outcrops, the drilling of the well was accompanied by no crooked hole tendencies such as is usually the case when a well is being drilled in steeply dipping formations, and lastly the overlying granitic arkose was probably basal Cretaceous, thus fixing the upper limit of the possible age of the formation.

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[10]Determination based on fossils discovered near Vinales and classified by Dr. Carlos de la Torre: classification agreed to by Dr. T. W. Stanton. See Anales, Acad. Cien. Med. Fis. y Nat., Rev. Cient. t. 47, pp. 187-191, Habana, July, 1910 and U. S. Geol. Surv., Prof. Paper 71, p. 552.

No occurrences of the Vinales limestone east of the Mendez well are known to the author though it may be involved in the complex in the northern part of Santa Clara province between Santa Clara and Camajuani.

CRETACEOUS.

Formations believed to be of Cretaceous age possess an extensive development in this Island. The only available fossil determinations are from the province of Santa Clara and from near Santiago de los Banos, province of Pinar del Rio[11]. The last named occurrence is in a formation believed by the author to belong to the Lucero beds. The various formations believed to belong to the Cretaceous will be described as the Caystano formation and its possible stratigraphic equivalent, the Camajuani; the Luyano marls, and the Lucero beds.

CAYETANO FORMATION.

The Cayetano formation is a name suggested for the reddish argillaceous schists, phyllites, and shales with occasional sandstones and limestones which overlies the Vinales limestones on the north and south flanks of the mountain range between Pinar del Rio and La Esperanza. The formation along the road connecting these two places is excellently exposed and consists of ridges of folded reddish schistose or slaty shales in its upper portion and very closely folded, crumpled, and faulted schists, sandstones, and limestones near its base. All of this formation is of red color with the exception of occasional beds of purple and blue shales and a heavy bed of gray limestone, which occurs several hundred feet above the base.

The heavy limestone outcrops near Sumidero, north of Pinar del Rio, and may be part of the Vinales limestone brought up by faulting rather than a part of the Cayetano formation.

A company formed by Mariano Medina, and financed by ex-president Jose Miguel Gomez, drilled a well starting in this formation at La Esperanza, on the north coast of the Island. This well is variously reported to have reached depths of 1100-1400 feet

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[11]Notes by T. Wayland Vaughan, U. S. Geol. Survey, Prof. Paper. No. 71, p. 643.

and, from the apparent general structure, one would have expected it to encounter only rocks of the Cayetano formation throughout. At the time of the author's visit in 1915, however, the well was only 830 feet deep and had encountered but little limestone, probably the Vinales, from a very shallow depth downward.

Camajuani Formation.

Cretaceous formations consisting of a basal bed of arkose and of a fossiliferous hard grayish limestone immediately above, followed by various limestones and shales, outcrop over a wide area in the northern part of Santa Clara province. The age of this formation has been determined as Cretaceous by Vaughan[12] who found such typically Cretaceous fossils as *Barrettia, Requienia,* etc.

The basal arkose is composed very largely of material derived from the serpentine and granite. The 300 feet of granitic arkose found in Menendez Well No. 1 of the Cuban Oil Company is apparently the basal arkose of the Cretaceous in this area.

Luyano Marls.

At Luyano in the vicinity of Havana and near Mariel, as well as at other places, a series of white marls, shales, limestones and grits outcrop. Though one cannot be quite sure of stratigraphic position and relations where the rocks are so severely folded as in the areas of Cretaceous outcrop, this formation is believed to be the equivalent in part of the upper Cayetano or overlying the Cayetano, and to be in turn overlain by the Lucero beds.

The white marls or chalks are the predominating feature of the Luyano though grits in beds of 25 to 30 feet thick and some thinner conglomerates have been observed. The thickness of the formation is not known, only some 150 to 200 feet having been observed continuously because of the severe folding and frequent faulting, but the formation is probably much thicker. The gas producing rock in the well at Puentes Grandes is probably of this formation.

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[12]U. S. Geol. Survey, Prof. Paper No. 71, p. 643.

Lucero Beds.

Apparently overlying the Luyano marls conformably is a series of alternating thin bedded shales and sandstones containing occassional thick beds of sandstone, conglomerates, grits and occasional limestones. This formation is well exposed at various points over a wide area but may be seen as well at kilometer 8 on the Guines Branch of the Havana Central Railroad as at any other point. The formation is here typically thin bedded, folded and faulted and has the characteristic yellow and tan colors due to weathering. On a rough estimate, some 250 to 300 feet of strata are exposed though the formation is doubtless much thicker.

At its various outcrops, where the serpentine comes in contact with sedimentary rocks, the contact formation is usually Lucero beds. It is often metamorphosed, a condition that is partticularly noticeable in the outcrops between Guanajay, Bahia Honda, and westward. It contains some conglomerate, including serpentine and limestone pebbles. In most places the outcrop forms a more or less narrow belt around the edge of serpentine outcrops indicating that the igneous rock, from which the serpentine was derived, was generally intruded into this formation.

The Lucero beds have been encountered by most of the wells drilled in the Island except those starting in the serpentine. The oil produced in the Shaler Williams well may come from this formation. A well was drilled by the Havana Oil Company to a depth of 1850 feet at a point about 8 miles south of Mariel Bay and started in this formation. The author has not been able to consult the record of formations penetrated by this well, but noticed some serpentine among various materials in the slush pit. The well encountered some gas and oil and considerable quantities of salt water.

Bejucal Limestone.

In the central part of Havana province at Bejucal and eastward, a thick series of limestone interbedded with calcareous shale and marl out crops.

The middle and lower parts of the formation contain considerable beds of shale, a condition which is of very great importance since it affords one of the most satisfactory cap rocks

to be found in the Cuban section and suggests a possibility of the existence of conditions favorable to oil accumulation.

The age of this formation is not known since no fossils have yet been encountered but, as it is believed to be younger than the Yumuri limestone, an Eocene age is tentatively ascribed to it.

The thickness of the formation is not known but it is believed to be 3,000 to 3,500 feet. Two wells are being drilled by the Antillian Corporation at points 17½ miles south of Havana and 26 miles southeast of Havana. These wells, according to last report were 3000 and 2825 feet deep respectively, and are believed to have been drilling in the Bejucal limestone throughout their entire depth.

The formation overlies the older formations unconformably and is in turn overlain unconformably by the Yumuri limestone.

The formation is well exposed and structure can be worked out in it without great difficulty. The dips are usually low though a dip greater than 50° was found at one place.

Yumuri Limestone.

The Yumuri limestone consists of an extremely porous, cavernous limestone which rests unconformably on the younger formations and outcrops generally in a cape around the coast of the Island where it has been examined by the author. The north south section across the Island at a point a few miles east of Cardenas shows only outcrops of this and younger formations.

The formation is altogether limestone and is so extremely porous and cavernous that one can hardly conceive that it would, no matter how thick, form an effective cover or cap rock for containing oil. It might act as an excellent reservoir if it were properly covered, but such condition does not exist. It is difficult to exaggerate the porosity of this formation. Drill cuttings from a depth of 600 or 700 feet in one of the Felicidad wells were found to be stained with red soil which had been brought down by percolating waters. It is entirely too porous to act as a cap rock, cannot serve as a reservoir rock for lack of cap, is unconformable over the underlying formations to such an extent that

its structure is not the least index to the structure of the underlying formations and consequently serves only to mask formations which might be oil bearing.

The thickness of this formation is not known. It is excellently exposed in the gorge of the Yumuri River at Matanzas where it rests unconformably upon the Lucero beds. Some 750 to 800 feet of the formation were measured at this place. The greatest known thickness, some 1670 feet, was encountered in the Dos Toros well of the Cuban Oil Company a few miles Northwest of Cardenas.

The formation contains the famous Belmar caves near Matanzas. Because of the great range of temperature and excessive humidity, it weathers into very sharp points and ridges called, by the natives "dientes de perro" or dog teeth. It also weathers into a deep residual soil and often forms immense flat monotonous plains or savanahs, miles in extent, which are so remarked a feature of Cuban topography.

Vaughan[13] found characteristic upper Oligocene fossils in this formation at its type locality, the Canyon of the Yumuri near Matanzas, and considers it to be of Upper Oligocene age. Upper Oligocene fossils were also collected at Consolation del Sur near Pinar del Rio.

QUATERNARY[14]

There are formations of coral reef rock younger than any of the formations described, at various places in the Island; also a wide spread occurrence of terrace gravels in the southern part of the province of Pinar del Rio and generally along the south side of the Island, and alluvial deposits of recent age, but these are of no concern to the present report.

IGNEOUS ROCKS.

Igneous rocks, aside from serpentines and granites already mentioned in conection with the basal complex, are of fairly

[13]U. S. Geol. Surv. Prof. Paper No. 71, p. 723.

[14]For more complete description of the younger rocks, see R. T. Hill's Notes on Geology of the Island of Cuba, Bull. of the Mus. of Com. Zool., Harvard Coll., Vol. XVI, No 15,

common occurrence in the Island and probably range up to post-Cretaceous age. Syenites have been reported from just south of Campo Florido and at various places in the eastern part of the Island, and various igneous rocks are exposed in the western part of Havana province near Madruga. Some obsidian was encountered in wells drilled at Motembo and diorite outcrops in the quarry already mentioned near Regla and at San Diego Valesquez.

Dykes are reported from Santa Clara and various points to the eastward. R. T. Hill[15] reports a dyke near Viento, south of Havana.

Structure.

The general structure of the Island is broadly anticlinal, the structural axis being parallel to the major geographical axis though somewhat nearer to the north than to the south coast. The flanks of this anticline or anticlinorum are not of equal extent, the slopes being broader and the dips gentler and more uniform on the north than the south side.

This general structure just described is the result of late Tertiary or post-Tertiary folding. The pre-Tertiary rocks are closely folded, standing on edge and even overturned in many places, and very much faulted indicating most violent movement before the younger Tertiary rocks were deposited. Traversing along the main road from Guanajay to Bahia Honda, for instance, one finds the Lucero beds folded into a series of very close east-west striking synclines and anticlines. Pre-Tertiary movements were so severe and complex that their full interpretation can come only after some extremely detailed mapping of Cretaceous rocks.

A section across the Sierra Organos between Pinar del Rio and Esperanza shows an anticlinorum, the axial or main mountain mass consisting of an east-west striking anticline of the more resistant Jurassic limestone, flanked by the closely folded and faulted softer Cayetano beds. The structure is further complicated by folding or faulting as witness the very shallow depth to the limestone in the wells drilled at Esperanza.

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[15]Op. cit. page 287.

Further east, a hurried section across the Sierra Rosario between Bahia Honda and San Cristobal shows folding apparently modified by step or block faulting so that the prevailing dip is northward in the main mountain mass and southward in the northern coastal plain.

A north-south section through Guanajay shows an anticline, between the town and the north coast of the Island, from which the Tertiary limestones dip gently away to the north and south. The steeply folded and faulted Cretaceous formations and small patches of serpentine are exposed along its crest.

This anticline plunges eastward, the Cretaceous exposures ending near Central Santa Luisa but reappearing again in a small closed dome at the El Cano.

Eastward, the Cretaceous reappears in the valley of the Almendares River near Havana and is exposed in a wide area whose southern boundary follows generally the curious circular course of the Almendares River as it swings in from Cotorro to the westward. This broad exposure must be the result of post-Tertiary doming or folding. The anticline continues eastward to Matanzas, the serpentine outcropping intermittently along its axis, flanked on both sides by the Cretaceous formations, and these in turn flanked by the north and south dipping Tertiaries.

South of this Havana-Matanzas anticline or anticlinorum is another roughly parallel anticline or anticlinorum generally termed the Bejucal-Guines anticline. Only the Tertiary rocks outcrop along its axis. It is being prospected at present by the wells of the Antillian Corporation.

Cretaceous rocks and serpentine are again brought to the surface by folds at Madruga, south of Matanzas near Jovellanos, and at the Tetas de Camarioca west of Cardenas.

As has been previously noted, a north-south traverse across the Island a few miles east of Cardenas, shows only rocks of Tertiary and younger age.

In the extreme eastern part of Matanzas province and in the province of Santa Clara and eastward, the structure becomes again more complex and it is not well enough known to the author to justify any attempt at description.

The author cannot see at the present time that structure, generally regarded as desirable in oil field practice, presents any very reliable criterion for well locations in this region. Structure in the Vinales limestone outcrop leaves one with no known caprock impervious enough to retain the oil, no knowledge of the thickness of the limestone beyond 2000 feet, and no information as to the underlying formation. An exploratory well in this formation might furnish a key for the solution of the Cuban problem. The Cretaceous formations have been too violently disturbed in most places visited by the author to suggest possibilities for the accumulation of more than small pockets of oil unless covered by a suitable cap rock such as the lower part of the overlying Bejucal formation. Certain of the Cretaceous beds, when overlain by the more or less impervious Bejucal formation, present stratagraphic conditions favorable to the accumulation of petroleum and *may present suitable structural conditions no matter what the apparent structure of the Bejucal formation may be.*

This condition the author conceives to be true because the Cretaceous, where it outcrops, is generally dipping at a high angle and is structurally unconformable to the overlying and generally gently dipping Bejucal limestone. Manifestly, the sealing of vertical standing or steeply dipping sands by overlying impervious beds forms a suitable reservoir for oil accumulation, no matter what the structure of the overlying beds may be. Such accumulations are likely, however, to be of very limited lateral extent and hard to find with the drill.

The author does not wish to be understood as believing that oil cannot be found in an anticline in the Bejucal formation. In fact he even recognizes that the anticline might have a slight tendency toward accumulation, especially if the buried steeply dipping sand strikes at right angles to the strike of the structure, but it is his belief, that unless an oil sand should be found in the lower part of the Bejucal or unless the unconformity between the Bejucal and underlying Cretaceous should be found to be much less than he now believes to exist, areas of level lying Bejucal rocks will be equally attractive for prospective purposes to those presenting structural features such as are generally regarded as favorable to oil accumulation in other fields.

On the other hand, structure in the Bejucal formation may be only the most recent and faint expression of continuous folding which has been going on in the underlying formation.[16]

III. Petroleum and Asphalt Occurrences.

Surface evidences of the existence of the natural hydrocarbons in the subsoil of Cuba are of wide occurrence. Every gradation of the series from hard glistening asphalt, through the malthas, heavy and light oils, and natural naphthas to natural gas have been found. Seepages of oil and gas or asphalts have been reported from every province of the Island. They are known to extend from near Querto Padre in Oriente province to Esperanza in Pinar del Rio province, a distance of some 475 miles, though they are of most common occurrence between Esperanza and the eastern boundary of Santa Clara province in a zone 5-30 miles wide and some 300 miles long and lying near the north coast of the Island.

Detailed description of the occurrences by provinces from east to west is as follows:

Oriente Province.

The only asphalt or oil occurrence known in this province (formerly called Santiago de Cuba) is the Farola seepage which lies about two miles SWS of the Ingenio San Manuel, and about a quarter mile south of La Farola cross-road store and just off the road. The seepages of light maltha or heavy oil are in the serpentine and have been mined to some extent. According to a native guide, more than a hundred casks of this oil have been mined and used for lubricants at the nearby San Manuel sugar mill. This report is probably exaggerated as to amount and mistaken as to use since the oil very apparently is heavy and of asphalt base.

[16]Such conditions would be very similar to that found in the Healdton, Oklahoma, field, but it is not known whether the lower Bejucal contains any beds capable of forming an oil reservoir such as those of the Permian and Pennsylvanian of Southern Oklahoma, which overly the Ordivican unconformably. See Sidney Powers' Healdton paper, Econ. Geol., Vol. XII, pp. 594-606, 1917, especially the section on page 597.

There are also vague reports of oil seepages in the valley of the Cauto River, and of bitumens near Tunas, Manzanillo, and in the barrio of Guisa.

Camaguey Province.

The only known occurrences of the natural bitumens in this province, formerly known as Puerto Principie, consist of a seepage of heavy oil (10° Be.) said to produce as much as a barrel per day which is found a short distance east of the Jatibonica River (western boundary of the province) in the jurisdiction of Moron, and a vein of asphalt which outcrops in the eastern or Camaguey bank of the same stream. These deposits belong to the same group as the Jatibonica asphalt mine.

The seepage of oil or maltha is known by the name of 'Mal Nombre' and occurs in a region of serpentines and metamorphosed rocks.

Santa Clara Province.

Deposits of asphalt and oil and gas seepages are of fairly common occurrence in this province.

The Jatibonica asphalt mine, some 8 miles southeast of Mayajigua, is reported to be a deposit of hard grahamite, of brilliant luster, having a strong odor of petroleum and associated with maltha or heavy oil. Belt[17] who visited the deposit in 1914, states that the vein occurs in serpentine some 200 yards south of its contact with schists and metamorphosed limestone. There are reports of other asphalt deposits in this vicinity including outcrops of two asphalt veins in the Santa Clara bank of the Jatibonica River.

Greit[18] states that a pocket of 14° Be. oil was encountered at a depth of 230 feet in copper mining operations in this general region.

Stains or patches of maltha have also been reported as occurring on the conglomeratic Tertiary limestone overlying rocks

[17]This and following statements ascribed to Belt are from a private report.

[18]This and following statements on Greit's authority are from a private report.

of the Camajuani formation at a point some 1¼ miles northeast of Camajuani. The author was unable to find this locality but was shown abandoned workings, said to have been asphalt mines, in the metamorphosed limestone on the east bank of the Camajuani River some 1¼ miles southwest of town. Hayes, et al[19] report various deposits in this vicinity of liquid asphalt.

The Eloisa asphalt mine lies a half mile south of the Santa Clara-Camajuani automobile road between kilometers 12 and 13 from Santa Clara near a ridge known locally as Loma de la Cruz.

The asphalt here, which is lusterless, melts easily in match flame, and has an odor of petroleum even when not heated. It occurs as veins and sheets in serpentine country rock which outcrops over a wide area.

Asphalt from this one was formerly used as gas enricher in Santa Clara but the mine has not been operated for some years and at the time of the author's visit in 1915, the workings were filled with water. Some 300 or 400 tons of asphalt had been mined and was then above ground.

The shaft is said to have been sunk to a depth of 35 metres and tunnels driven in several directions to distances of 100 metres. The vein is said to be 3 metres thick.

Hayes, et al[20], also report maltha from near a plantation called El Indio, about 15 miles northwest of Santa Clara in the direction of Sagua la Grande; a deposit of hard asphalt three miles from Ranchuelo and 12 yards from the Sagua River; and two undeveloped deposits on the Sugar plantation San Antonio, about 30 miles from Sagua la Grande.

Asphalt is also reported as occurring in the northeast part of this province at "La America," some 4 miles east of La Teja, province of Matanzas, and in a well drilled by railroad interests at Santa Clara city.

Seepages are reported in an east-west striking closely folded limestone basin, which is some 4 or 5 miles wide and lies between

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[19]Op. cit., p. 95.

[20]Op. cit. p. 94-95.

partially serpentenized igneous rocks near Placetas in this province. Oil seepages occur in the limestone and also at a point several hundred feet into the serpentines, beyond the contact on the south side of the basin.

Natural gas and a unique natural naptha[21] have been found in wells drilled at Motembo in the northwestern part of the province and gas escapes are of common occurrence in that vicinity. There are also vague reports of oil springs in the Peninsula de Zapata region.

Dr. Stokes[22] has described an oil from a spring near Santa Clara, known as Sandalwood spring. The oil is a peculiar oil with an odor resembling cedar wood.

Hayes, et al [23], note a reported occurrence of one of light petroleums at a place 3 or 4 miles west of Santa Clara city but state that a filled up well was the only thing in evidence at the time of their visit. This locality may be the same as that at Anton Diaz where wells were drilled by the Cuban Petroleum Company, Ltd. Gas was seen bubbling through the waters with which the cellars of the old wells were filled at the time of the author's visit.

Matanzas Province.

Asphalt is reported to occur near the ruins of Ingenio Santa Isabel in the northeastern part of this province. Some oil is also reported to have been encountered here in shallow wells dug in 1884-1889. Some two miles north of this place are the Menendez sulphurous water baths. The temperature of the waters is said to vary, becoming as high as 104° F. at times. About a half mile south of the Santa Isabel ruins is Menendez well No. 1 of the Cuban Oil Company, where the Vinales limestone from 1,115 to 2,385 feet was found to be impregnated with the asphaltic residue of what was probably a former oil deposit.

[21]This naptha has been described in greatest detail by Clifford Richardson, Am. Jour. Sci., 4th Ser., Vol. XXIX, pp. 439-446.

[22]U. S. Geol. Surv., Bull. 78, pp. 98-104, 1891.

[23]Op. cit. p. 99.

Asphalt and limestone have been mined from a number of pits in the Yumuri limestone at a point about 1 mile east and 1¼ miles south of the mouth of the Rio Palma, some 5-6 miles west of the Menendez well. The material mined from this place is said to have been used in paving operations in Cardenas, Matanzas, and Havana.

An oil seepage is also reported to occur just off the mouth of the Rio Palma and another is noted on an old map as occurring near the southern end of the Canal del Pargo between Cay Laborde and Cay General, some 15 miles from the mouth of the Rio Palma.

Asphalt is mined at Sabanilla de la Palma near the railroad and 2½-3 miles west of Hato Nuevo. A shaft some 90 feet deep has been sunk in the serpentine at this place and two short tunnels have been driven. This mine is said to yield some two-thirds barrels of maltha per day. The plant is equipped with a small refinery but is not operated at present. There are a number of seepages in the serpentine at this place and others in the Yumuri limestone about 1 to 2 miles to westward.

Three maltha springs are also reported to occur some 2-2½ miles south of Hato Nuevo between Livano and Gamutas. Peckham[24] also describes a large asphalt pit near Santa Catalina, some 2-3 miles from the Sabanillas seepages.

Gas seeps through the Yumuri limestone in the bottom of a 30 foot well some 4 miles SW of Macagua. The denouncement is called San Francisco and was at one time quite extensively advertised by its owner.[25] The author was also shown a flask of crude oil of good quality said to have come from a seepage in the vicinity of Macagua.[26]

Greit states that some 14 tons of asphalt were mined from a deposit in the Yumuri limestone at La Paz denouncement just south of Perico in 1899.

[24]Op. cit.

[25]See Diario de la Marina, June 16, 1915.

[26]By Ing. Guillermo Alonso.

The asphalt deposits of Cardenas bay have long been famous[27]. The largest deposit is said to be that of the Constancia denouncement, just off Diana Cay some 7 miles NEN from Cardenas. More than 20,000 tons are said to have been mined from this deposit before 1895. Another deposit lies in the western part of Cardenas bay and another important deposit is northeast of Cupey Cays[28].

Asphalt outcrops have also been reported at Cayo Cruz del Padre, Zalindo, Macho, and General Bustillo but these reports may refer, in part at least, to patches of asphalt thrown up by the sea rather than true deposits.

The owner of Progreso, 3½-4 miles southeast of Cardenas, states that several wells drilled for water near that place have encountered shows of asphalt.

Asphalt is reported near Tosca station between Coliseo and Jovellanos, an oil seepage at the baths of San Miguel southeast of Sumidero, near Coliseo, and hard asphalt on the lands of the old Ingenio Jinsey, evidently near the same place.

A small seepage is found at Felecia, a short distance SES of Cantel and 9 miles W by S from Cardenas, where oil and water seep out near the serpentine contact. It is here that the Alverez and Cuban Oil Company wells were drilled.

A few miles N W of these seepages are a number of heavy oil seepages along the sedimentary-serpentine outcrop. These are on the San Juan denouncement.

Oil seepages are also reported at Finca Blanca and Aranguron in the barrio of Camraioca.

There is also a seepage about a mile north of Recreo and 10 miles west of Matanzas. The oil comes out with water from a spring at a contact of a thin detrial conglomerate and serpentine, and the place is known locally as "La Mina de Chapopote."

[27]See Hance, J. L.—U. S. Consular Reports, Vol. 47, No. 172, pp. 126-128, 1895.

[28]See Cardenas and Santa Clara Bays chart of U. S. N. Hydrographic Bureau.

Greit states that asphalt denouncements have been made in the Barrios of Bacunayagua and Canasi; that asphalt was found in a water well 70 feet deep at a farm of the American Red Cross Society near Ceiba Mocha, and that asphalt was also reported from the west side of Pan de Matanzas but that he was unable to verify the report.

Havana Province.

A maltha seepage is reported in the serpentine about ½ mile west of Madruga on the Havana-Matanzas road and an asphalt vein is reported near the same place, as well as a maltha seepage 1½ miles east of Madruga.

There are also said to be a 3 foot vein of hard asphalt striking ENE by WSW on Rosario plantation near Aguacate and various occurrences of hard and soft asphalts in the municipality of Jaruco and hard asphalt deposits near Bainoa and Jiboca.

Hayes, et al[39] note that viscous asphalt was seen exuding along the joint planes in syenite rock which was being quarried at a point about 1½ miles southeast of Campo Florido at the time of their visit. The old asphalt mines of Jesus del Potosi and Santa Rosa, in the same general region, are at present abandoned and "caved in." Belt visited the locality in 1914 and states that the entire region is serpentine and syenite with occasional small patches of highly metamorphosed Cretaceous sediments.

There are a number of active oil seepages in the serpentine about 100 yards from the contact with the sedimentaries near Bacuranao where oil is being produced at present.

Oil of good quality was found in fairly large amounts (several litres per day) oozing from along the walls of a diorite dyke in serpentine and from joint planes and cracks in the igneous rock itself at a quarry just off the main road between Regla and Guanabacoa. Oil also oozes out with mineral waters from springs in the serpentine at the Santa Rita baths in Guanabacoa.

Gas is found in wells at Puentes Grandes and asphalt, both hard and soft, has been mined at Finca de las Minas, near

[39]Op. cit., p. 91.

kilometer 12, on the Havana-Guines road. This general region is apparently one of Cretaceous sediments.

Oil is often found in quarrying the Yumuri limestone near Jamaica.

Greit notes that a number of outcrops of hard asphalt are found to the north of Tetas de Managua and near San Antonio de Barreta.

There are a group of asphalt mines some 4-5 miles ESE of Bejucal which were formerly producing properties of importance. These deposits consist of veins of asphalt in the Bejucal limestone near the west end of the Bejucal-Guines anticline.

Small amounts of gas have been encountered in both of the deep wells now being drilled along the Bejucal-Guines anticline by the Antillian Corporation.

There is an abandoned asphalt pit in the eastern edge of the village of Punta Brava. It is some 600-800 feet north of the Havana-Guanajay automobile road and is in the Yumuri limestone just west of the Tertiary-Cretaceous contact on the Cano dome.

Gas and oil have been encountered in the Shaler Williams well, drilled at Guayabal.

A considerable seepage of petroleum is found in Cretaceous sediments which are exposed along the axis of the post-Tertiary anticline near the ranch of Coroneles. About two miles west of this place, on the Finca San Pedro, is a spring of cold sulphurous water which carries drops of oil with it. This seepage is in serpentine and also near the anticlinal axis. Hard asphalt veins outcrop in the bank of the Rio Banes a short distance north of Banes. These deposits are in a region which was formerly a part of the province of Pinar del Rio.

Hard asphalt is reported to outcrop to the northeast of the Sierra Canada and at the base of Cerro Natividad, in the Isle of Pines, as well as along the line of keys, Islas de Mangles, north of the Island including Cayo la Torre and Cayo Alacran.

Pinar Del Rio Province.

Patches of asphalt or maltha are said to have been found on the rough exposed surface of the reef at Mariel and there is said to be a deposit of hard asphaltum one mile south of Mariel Bay on the Canas plantation[20]. Some 3 miles SSW of the bay is a seepage of liquid petroleum near which a deep well encountering small amounts of oil and gas and some water was drilled.

About a mile north of this well is a deposit of hard asphalt which has been worked extensively during the past. The workings were abandoned and full of water at the time of the author's visit but Belt visited the mine in 1914 and reports that the asphalt occurs as a vein some two metres thick between vertical beds of sandstone and shale.

Southeast of Rosario, near Gayajabos are abandoned works where hard asphalt was formerly mined.

A submarine seepage just off shore at Herradura is reported by fishermen and the author is of the opinion that it actually exists since patches of maltha are found along the beach.

There is an important and almost unworked asphalt deposit about one mile NNW of Cacarajicira and 8-9 miles SW of Bahia Honda. Here are two veins striking approximately N20°W in the closely folded Cretaceous rocks. The westernmost vein is some 8-10 inches thick at the top and 30 inches wide six feet lower down, the lowest point seen.

Just east of Martillo, which is south of Bahia Honda, is a mine of what is generally regarded as asphalt but may be bituminous shale or slate and some three miles to the east is another mine of the same sort. A short distance NE of this latter mine is an old maltha pit.

About 100 yards offshore at Moralillo, due north from Coralillo, is a seepage on the floor of the sea. The author visited this locality in a rowboat on a calm day and was able to observe globules of oil constantly rising to the surface through the water and to collect oil in a gourd. The oil appeared to be of about 15-20° Be. in gravity. The Cuban Petroleum Company drilled a well near this place.

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[20]Hayes, et al, op. cit. p. 87.

Two wells are said to have been drilled in the valley of Rio Blanco some two miles from the Sierra Organos and four miles from the sea. Oil of 36° Be. gravity is said to have been encountered.

The well at Esperanza reported numerous gas shows below 400 feet. Asphalt and oil seepages of minute size are said to be of common occurrence in this region, in fact water from many of the shallow wells at Esperanza is said to be tainted with oil.

Belt reports a seepage in the shallows of the beach where maltha rises to the surface at a point five miles northeast of Esperanza.

Greit reports additional information regarding this province as follows: 8 feet of asphalt in a well drilled four miles north of Artemisa; asphalt at Loma de Chapopote, San Claudia, and Ana Teresa denouncements around the bay of Cabanas; 17 feet of asphalt at a depth of 30 feet at San Cristobal; maltha at Brujito, barrio of Minas; outcroppings of grahamite near San Joaquin about one mile west of Rio Santa Cruz and at the foot of Sierra Pinal del Rangel in the barrio of Santa Cruz, both Santa Cruz and Minas being in the municipality of San Cristobal; asphalt at 70 feet in a well at Pinar del Rio; asphalt at 100 feet in a well some seven miles north of Consolacion del Sur; asphalt outcrops near San Cayetano; an outcrop of oil impregnated sandstone at the base of a hill north of Ovas and another on the east side of the Sierra del Infierno near Isabelita.

A seepage of oil from a fissure in serpentine is reported at "Pacheco" denouncement in the municipality of Candelaria. This seepage is found in an EW striking valley in the Sierra Organos.

IV. Drilling Operations.

The author has no information regarding wells drilled in Oriente or Camaguey, the two easternmost provinces of the Island. Information regarding drilling operations has been given generally in the preceding part of this paper so that the present chapter will be used in order to make a brief resume.

Santa Clara Province.

Santa Clara: A well was drilled by the railroad at this place. It is variously reported as 700-2500 feet deep and to have passed through 7 feet of asphalt.

Motembo: Manuel Cueto and associates.

San Juan No. 1. In southwest corner of San Juan denouncement at Motembo. Drilled to depth of 950 feet with shows of naphtha at depths of 295 feet and 764 feet respectively.

San Juan No. 2. Some 100 feet south of No. 1. Drilled to depth of 950 feet with naptha at 590 feet.

San Juan No. 3. Some 70 feet west of No. 1. Drilled to depth of 800 feet with naphtha at same depths as in No. 1. Drilled to depth of 80 feet with diamond drill and completed with percussion drill.

According to graphic logs by M: Ceuto, from which the above information was taken, the three wells had the same logs consisting of:

0- 58 feet—Fine grained somewhat ferruginous diorite with a great quantity of black and dark smoky resinite which constitutes almost one-fourth of all of the rock.

58- 85 feet—Diorite with less hornblende and resinite.

85-106 feet—Feldspar without hornblende, apparently ferruginous and somewhat decomposed. Abounding in dark red resinite.

106-142 feet—Ferruginous feldspar with a great quantity of resinite of white, smoky, black and dard red colors.

142-166 feet—Feldspathic serpentine somewhat ferruginous with black, green, grayish green and bluish resinite.

166-173 feet—White feldspar, very pure, almost kaolinized. Contains black resinite and some chlorite in its lower half.

173-200 feet—Serpentine, dark green with feldspar, somewhat decomposed and black and smoky resinite.

200-690 feet—Greasy (esteatitoso) serpentine of light bluish-green color.

690-720 feet—Feldspathic serpentine and diallage of dark green color.

720-800 feet—Greasy serpentine of light bluish-green color.

800-903 feet—Feldspathic serpentine and diallage of dark green color.

903-950 feet—Greasy serpentine of light bluish-green color.

The resinite or resnite of the section is apparently volcanic glass or obsidian. The author has seen various bits of obsidian from the well cuttings at Motembo and Vaughan[31] notes that a portion of a well core consists very largely of volcanic glass and other volcanic material.

Cuban-American Oil Company.

In 1906, a company controlled by the same interests as the Cuban-American Sugar Company started drilling in this region, the first well being about 1,350 feet west of San Juan No. 1. Considerable difficulty was encountered and drilling was stopped on January 1, 1911, with the completion of the third well.

Results encountered in the wells were as follows:

No. 1—Abandoned at a depth of 420 feet (may have reached 700 feet but no record kept beyond 420 feet). The graphic log shows a bed of gravel at 70 feet; igneous rock at 89 feet; "sharp white gray sand" (?) at 104 feet; "black lime" (?) at 118 feet to 175 feet; "white marble" (?) at 180 feet; volcanic dyke and traces of serpentine at 208 feet; "black shale and shelly" (?) at 216 feet; "limestone" (?) and serpentine at 219 feet; and soft "blue slate" (probably serpentine) to 420 feet. At 280 feet the well was showing gas.

No. 2—Abandoned at 700 feet. Log a mixture of materials similar to those set forth in the log of No. 1. "Hard black lime" (?) from 608 to 616 feet and naphtha shows at 425 and 580 feet.

No. 3—Completed as a naphtha producer at a depth of 1,905 feet. Log also a bad mixture, with considerable "slate" reported in upper part of well. Oil and gas shows were as follows: Four hundred and ninety-two feet, gas show; 680 feet, half pint naphtha; 1,016 feet, gas for domestic uses; 1,320 feet, more gas;

[31]Hayes, et al., op. cit., p. 99.

1,420 feet, gas; 1,560 feet, tested an average of about 90 gallons per day of pure naphtha, salt water coming in later.

At the time of the author's visit in 1915, enough gas was being secured from one of the old Cueto wells for cooking purposes and the Cuban-American Well No. 3 was said to be making about 10 gallons of naphtha every other day.

This is an area of serpentine outcrop, the serpentine apparently having been subjected to more recent intrusion. The naptha may be the result of natural distillation of a heavier oil by the intrusion of the volcanic rocks into the serpentine.[32]

ANTON DIAZ.

Cuban Petroleum Company, Ltd.
La (Florita) Fe No. 1.
Started February 26, 1903, and completed April 27, 1904.

Log.

0-35 feet—Alluvium.
35-1,392 feet—Serpentine.
San Felipe No. 2.
Started August 15, 1904, and completed April 22, 1905.

Log.

0-743 feet (?)—Serpentine, some gas shows.

These wells were drilled in the lands of the estate of Felipe Silva, barrio Esperanza, near Santa Clara[33].

PROVINCE OF MATANZAS.

MENENDEZ.

Cuban Oil Company.

Menendez Well No. 1: This well was completed to a depth of 2,385 feet in 1915. Log is as follows:

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[32]There was a great potash excitement at Motembo during the latter part of 1916. The expert of the Cuban Government pronounced the supposed deposit valueless. See New York Times of Sept. 22, 23, 24, 25, 27, 30, Oct. 8 and 20, 1916.

[33]These wells have often been reported as near Esperanza, in Pinar del Rio, several hundred miles to the westward. Information from official log book and by courtesy of Mr. Beit, manager of Cuban Petroleum Co., Ltd.

0-60 feet—Travertine, remnants of recent limestone, and loose conglomerate of quartz, mica, and various other igneous material.
300-350 feet—Granitic arkose, including bits of serpentine.
350-2,385 feet—Vinales limestone.

The limestone was found to be impregnated with an asphaltic residue from 1,115 feet downward.

FELECIA CLAIMS.

ALVAREZ AND ASSOCIATES.

Well No. 1, 78 feet—black thick oil and water.
Well No. 2, 78 feet—water and traces of oil.
Well No. 3, 500 feet—dry.
Well No. 4, 500 feet—produced 100,000 (?) gallons of oil.
Well No. 5, 180 feet—dry.

CUBAN OIL COMPANY.

Felecia No. 1—

Log.

0- 650 feet—Yumuri limestone.
650- 790 feet—Lucero beds (?).
790- 970 feet—Serpentine.

Antigua Felecidad No. 1—

0- 990 feet—Yumuri limestone.
990-1,040 feet—Lucero beds (?).
1,040-1,044 feet—Lucero beds and serpentine.

Dos Toros No. 1—

0-1,670 feet—Yumuri limestone.
1,670-1,835 feet—Lucero beds (?).
1,835-1,850 feet—Lucero beds and serpentine.

These wells were drilled at a seepage near Cantel, west of Cardenas, and were dry holes. The Dos Toros well is some distance east of the other wells and nearer Cardenas.

SABANILLAS.

The Cardenas-Sabanillas Petroleum Company is reported to have a derrick up near the Sabanillas seepages[34].

MATANZAS.

[34]Oil Trade Journal, June, 1917, p. 58.

Rig and tools for a location to be drilled in the Yumuri valley near Matanzas have been reported.

HAVANA PROVINCE.

MINAS DISTRICT.

Union Oil Company—

Well No. 1—Oil at 540 feet and salt water at 690 feet. Well reported to have produced 1½ barrels per day of oil.

Well No. 2—Some 90 feet west of No. 1. Abandoned at 350 feet.

Well No. 3—Some 90 feet north of No. 2. Hole plugged at 370 feet.

Well No. 4—Some 160 feet west of No. 3. Reported to have passed through oil at 353 feet and 548 feet. Completed at 575 feet. Had produced a total of some 1,900 barrels of oil from August 15, 1916, to March 15, 1917, and was reported to be pumping 12 barrels per day at the end of January this year[35].

Well No. 5—Some 400 feet east of Well No. 4. Brought in February 15, 1917, at a depth of 1065 feet. Oil sand reported from 920 feet to 1,000 feet. On May 3, 1917, the well was shot and is reported to have resulted in a production of 200 barrels per day. According to recent reports it is producing some 60 barrels per day at present.

Well No. 6—Abandoned as a dry hole at 1,995 feet.

Well No. 7—Drilling suspended at 700 feet. This well had a showing of salt water and oil at 550 feet.

Well No. 8—Reported to have been drilled in during the month of February, 1918, and to be good for 100 barrels per day at a depth of 1,019 feet[36].

Cuban Petroleum Company—

Well No. 1—Some 250 feet NE of Union Oil Company No. 4. Completed March 14, 1917, pumping 150 barrels per day

[35]Oil, Paint, and Drug Reporter, Feb. 11, 1918, p. 51.

[36]Oil, Paint, and Drug Reporter, Feb. 11, 1918, p. 51.

from a depth of 865 feet. Well said to be pumping 10 barrels per day at present.

Well No. 2—Reported abandoned dry hole at a depth of 1,095 feet. This well is reported to be about 1 mile west of the proven area.

Chretiland Petroleum Company—

Well No. 1—Some 16 miles east of Havana and 5 miles from north coast. Dry hole at 1,232 feet, having been drilled in serpentine throughout.

Well No. 2—One mile east of No. 1 and 2 miles south of the Union Oil Company wells. Reported shut down at a depth of 1,030 feet.

Republic Oil Company—

Well No. 1—Well reported to be producing 12 barrels per day from depth of 917 feet and drilling at 1,125 feet.

Cuban Standard Oil Company—

Well No. 1—Drilling suspended at 410 feet.

Gulf Petroleum Company—

Well No. 1—Drilling at 870 feet.

United States Oil Company—

Well No. 1—Drilling at 1,230 feet.

Cuba International Oil Company—

Well No. 1—Drilling at 125 feet.

Benedum and Trees—

Well No. 1—Rig up.

Cuba American Oil Company—

Well No. 1—Drilling at 400 feet.

Guanabacoa Oil Company—

Well No. 1—Rig up.

The oil produced from this district is said to be 26° Be. in gravity and to yield 13% of distillate of 0.7345 sp. gr. up to 150° C., and 31% of distillate of 0.8162 sp. gr. from 150° C. to 300° C.

The deposit as proved to date is very small and the oil is said to come from a "sand" near the serpentine contact on the north side of the Guanabacoa serpentine mass, a short distance from the contact with the sedimentaries[17].

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[17]Logs of Union Oil Company wells Nos. 2, 4 and 5 are given in the Oil, Paint, and Drug Reporter of July 9, 1917, but as to the formation classifications, they are of doubtful value.

GUINES.

Antillian Corporation—

Well No. 1—Some four miles northwest of Guines. Drilling suspended at 3,006 feet. Company states oil not expected at depth shallower than 4,000 feet.

MANAGUA.

Antillian Corporation—

Well No. 2—Some three miles south of Managua. Well 2,825 feet deep. Company states that oil not expected at depth shallower than 3,500 feet.

CALVARIO.

El Triunfo Oil Company—

Well No. 1—Said to have been abandoned at a depth of 76 feet.

ARROYO APOLO.

El Triunfo Oil Company—

Well No. 2—Drilling at 156 feet.

GUAYABAL.

Sinclair Gulf-Shaler Williams—

Well No. 1—Depth 1,565 feet. The log of this well shows limestone, clay, and sandstone to 1,110 feet, the depth of the well in 1915; with sulphur water at 382 feet, gas at 535 feet, a flow of gas at 742-805 feet, water at 800-805 feet, oil at 885 feet and 895 feet, gas at 908 feet and oil at 912 feet. The well is at present reported making gas and a very small quantity of oil from 1,300-1,565 feet.

PUENTES GRANDES.

Tropical Engineering Company—

Well No. 1—This well, north of the brewery buildings, came in a gasser at a depth of 718 feet on December 6, 1913. It is now abandoned. E. B. Hopkins[33] reports log of the well as follows:

0-60 feet—White limestone.

60-718 feet—Limestones, serpentine, and shales. Gas at 700-718 feet.

Well No. 2—Drilling at 1,277 feet.

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[33]Personal communication with the author.

Pinar Del Rio Province.

MARIEL.

Havana Oil Company—

Well No. 1—Abandoned at 1,850 feet after having encountered oil and salt water.

MORILLO.

Cuban Petroleum Company, Ltd.—

Well No. 1—Abandoned as a dry hole at 1,811 feet, having encountered only serpentine.

CONSOLACION DEL NORTE.

Cia. de Minas de Petroleo—

Rio Blanco No. 1—Dry hole at depth shallower than 200 feet.

Rio Blanco No. 2—Dry hole at depth shallower than 200 feet.

LA ESPERANZA.

Mariano Medina and Associates—

Well No. 1—A dry hole at depths variously reported as 830-1,400 feet at the town of Esperanza.

V. Occurrence of the Oil.

One of the most remarkable things about the occurrence of the various members of the petroleum family in this region is their association with igneous rocks and with serpentines believed to have been derived from the alteration of igneous rocks. The area presents a paradise to those who argue igneous origin of petroleum from every association with igneous rocks.

The author believes that the oil has ultimately been derived from the Jurassic limestones or older sedimentaries, that the igneous rock from which the serpentines are derived were intruded, for the most part, into the Cretaceous rocks which overlie the Jurassic, and that the asphalt deposits and oil seepages found in the serpentine and igneous rock are the result of oil seeping from the underlying sedimentaries or from patches of the sedimentary rocks which have been caught up in the serpentine.

If such conditions exist, and if the serpentine is thin enough to be penetrated by the drill, one might find oil underneath the serpentine. No well drilled into the main mass of the serpentine has yet gone through it so far as is known to the author.

Because oil has been found in a serpentine at Thrall, Texas,[39] attempts have been made to argue an analogy to the Cuban occurrence. No mass of serpentine in Cuba occurs under conditions similar to those at Thrall.

Whatever the origin and source of the oil, all yet produced in anything like quantity has come from the serpentines or from its contact with sedimentary rocks. Three most interesting tests now drilling, the Shaler Williams well and the wells of the Antillian Corporation, should reveal further information as to the possibility of oil being found in the sedimentaries, though it is entirely possible that any of the three wells may go into the serpentine or igneous rock.

The author will not attempt to repeat the various theories he has advanced as to the effect of structures and unconformity in connection with Cuban petroleum geology, but will call attention to the wide-spread occurrence of hard asphalt and natural naphtha as evidence that the original oils of Cuba have been subjected to metamorphism as well as the containing rocks and to the consequent probability that much oil has been lost.

There is ample evidence that oil still remains, but, in the author's opinion, the probability of developing a great oil field in the Island is not good and the operator must face conditions which increase several fold the hazards of that most hazardous of all operations,—wildcatting.

In conclusion, the author would like to call attention to remarks by Samuel Peckham, author of our first great compendium on petroleum. These remarks were published[40] in comment regarding prospects in Cuba some eighteen years ago but might well have been written yesterday.

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[39]See The Thrall Oil Field, by J. A. Udden and H. P. Bybee, Bull. Univ. Texas, No. 66, 1916.

[40]Amer. Jour. Sci., 4th ser. vol. XII, p. 41, 1901.

"Until a sufficient amount of work has been done by parties personally interested in the property, to demonstrate beyond question the existence upon or under it of actual value, these surface indications, though exhibited on a large scale and over a wide area, are not in any manner in themselves a source of prospective wealth but are rather only an incentive to cautious, and very careful prospective drilling. The wells that have been drilled, while demonstrating that oil can be produced by drilling, have been very moderate producers and extremely short lived and are, therefore, quite as largely indications to extreme caution as a stimulus to even experimental outlay."

New York, February 11, 1918.

ON THE MIGRATION OF PETROLEUM THROUGH SEDIMENTARY ROCKS.

By A. W. McCoy, *Bartlesville, Oklahoma**.

In the science of petroleum geology the worker is confronted with two principle problems: (1) formation; (2) accumulation.

The general practice accepts the organic theory of formation, namely, that the oil has been formed from various types of animal and vegetable remains, buried in the sedimentary rocks. In view of this fact, prospective areas are confined to wide synclinal troughs of sedimentary formations. Otherwise no special condition of the sedimentary series has been considered essential.

Some form of the anticlinal theory is generally recognized as the controlling factor of accumulation. In the main this theory assumes that the oil, being lighter than the water in water-soaked sediments, moves up the dip of a formation until it is trapped by a reverse in structure and is collected under and along the sides of the fold. Consequently, petroleum geology has evolved into an engineering problem of obtaining elevations on outcropping formations and by contouring the surface of a single formation, locating the folded areas.

If the assumption for migration is correct, the problem is comparatively simple, and no special study of sedimentation is necessary. However, there are some very good reasons to think that such an assumption is not true.

It is impossible for oil to migrate any great distance in the oil-bearing formations of the Mid-Continent field.

The movement of oil in water-soaked sediments is almost entirely a problem of surface tension. Water having a greater surface tension and attraction for rock surfaces than oil, moves into the smaller pores occupied by the oil and forces it into the larger openings. Such movement is characteristic as long as the openings are less than 0.1 mm. Where the sand grains are un-

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usually large (3 mm. in diameter or over), or where induced openings have been made locally in some hard formation, sorting due to specific gravity is free to take place if the unbalanced weight overcomes the friction of the movement. On an incline of less than 2 degrees in an open cavity as shown by Daley[1] the friction overcomes the unbalanced weight and no movement results.

Relative forces thus affecting oil movement can be figured from the size of the openings in the rocks[2]. In a shale at a depth of 1,500 feet where the openings are 0.7 micron the capillary force of the water to replace the oil is about 2,700 pounds per sq. in.; the unbalanced force due to specific gravity is less than 0.1 pound per sq. in.; and frictional resistance is probably a fraction of a pound per sq. in. As the openings become larger the capillary expelling force of the water becomes less, and when these have reached 0.5 mm., this force is zero. Then the unbalanced specific gravity and frictional resistance are the only forces to be accounted for. Such places are only local in the sedimentary series and the great majority of openings in oil-bearing formations are much smaller. The force necessary to make oil migrate through a wet shale (openings 0.01 micron) at a depth of 1,500 ft. is about 4,100 pounds per sq. in. This is 1,500 pounds per sq. in. more than the combined rock and complete hydrostatic pressure. Consequently, it is utterly hopeless to assume migration of oil through wet shale. Even when the openings in a sandstone are as much as 0.1 mm. in diameter, the capillary resistive power is about 0.4 pounds per sq. in., compared with 0.1 pound per in.—the unbalanced force due to specific gravity. The instant an oil particle migrating in water sediments reaches a series of openings larger than those surrounding, it stops, and remains there indefinitely, as long as these surrounding openings are less than 0.1 mm. All sandstones are irregular and a series of openings larger than 0.1 mm. is never very extensive.

Experimentally, migration of oil in wet sand can be shown to be impossible where the grains are the size of the average sandstone (0.2 or 0.3 mm.). Oil placed in wet sand will

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[1]A. I. M. E., vol. LVI, p. 736.

[2]Johnston & Adams, Journal of Geology, vol. XXII., p. 13.

remain practically where it is placed and show no tendency to separate out according to the gravity.

On the outcrop the sands in the oil-bearing formations are not continuous but lenticular. By careful study of sands from well logs in different Mid-Continent fields the lenticular property of the sands become more evident. Water analyses also corroborate this fact. Results from 100 analyses to date point to the fact that each sand lens carries a definite water, uniform throughout and differing in some respect to water of another lens. These waters are connate sea waters uncontaminated by surface water. In nearly pure silica sands the water differs little from sea water. In limey members or where other soluble minerals are noted the water is much higher in total solids than sea water. Recent work seems to indicate that the change from normal sea water can be accounted for by the minerals in and surrounding the water horizon. If the water shows no connection between different lenses in a sedimentary series surely continuous sands or porous zones cannot be expected, and consequently the analyses check the impossibility of migration from one lens to the other.

The above line of reasoning leads to the conclusion that extensive migration of oil is very improbable, and suggests that the present occurrences of oil are "in situ" phenomena. The place of origin of petroliferous deposits, therefore, assumes paramount importance. It has been shown in previous paragraphs that mechanical difficulties would make it impossible for oil particles widely disseminated through a formation to collect into concentrations of commercial significance. The nature of the process of accumulation, therefore, necessitates a considerable concentration of organic matter in the original sedimentation. Theoretically, the zone of rock forming material richest in animal and vegetable matter would be at some distance from the shore of the old basins and yet so close to shallow water that it would receive abundant organic remains. Here the percentage of hydrocarbons per volume of debris is much greater than in either the area very close to the shore, or that out in the interior of the basin, although more animals may have died closer to the beach. These areas richest in original organic matter would run in belts parallel to the old shore lines. Then if conditions favorable for local migration into reservoir rocks occur along these zones, pro-

ductive pools will result and these, too, will lie in broken lines or chains parallel to the old shore.

This leads to an inquiry into the formational processes of organic shale and its relation to paleogeography. Considerable discussion has been published concerning black carbonaceous shales and a review of such a large problem cannot be taken up in this paper. However, after some study of the conditions under which shales are forming at the present time, and noting similar factors in the shales of former geologic periods, the general conclusions are as follows:

Only a certain kind of carbonaceous shales produce oil. They are comparatively thin, varying from a few inches up to several feet.

The amount of liquid hydrocarbons per ton of material varies from 10 to 50 gallons in the richest of these beds.

These shales are only a few miles wide and run in belts parallel to the shore of the old basin, except in very narrow basins where they would be formed over the whole area. In relation to the geologic section they are confined to the shore phases of the typical marine sediments.

NOTE: The evidence for the above conclusions, the description of conditions under which such shales are formed, the paleogeographic maps of Pennsylvania and Permian, together with their relation to the Mid-Continent oil fields, and the problems of accumulation, will probably be published at some later date.

THE DISTRIBUTION OF UNDERGROUND SALT WATER AND ITS RELATION TO THE ACCUMULATION OF OIL AND GAS.

By ROSWELL H. JOHNSON, *Pittsburg, Pennsylvania.*

To the geologists especially interested in oil and gas, the question of the direction of the migrating waters has become very important, following the important work of Munn. A controversy has arisen between Shaw on the one hand and Washburne and the writer on the other, as to the relative roles of ascending and descending waters, the latter having contended for widespread ascending waters well above sea level.

One of the reasons for this belief is the compression of strata after deposition by the accumulating overburden, which compacting would drive water diagonally and irregularly upward where passages permit, in general following bedding planes, as first pointed out by King. This position is attacked by Shaw, who cites the rarity of salt springs in deltas and shore regions, and the fact that the water of the polders of Holland is not salt. This objection holds only for a very shallow zone, which, all must grant, is prevailingly characterized by descending water. This zone, by virtue of topographic irregularities which cut bedding planes, and by virtue of solution channels, has an active gravitational circulation.

The zone of descending water may and frequently does extend somewhat below sea level near shores, by virtue of synclinal pervious beds. Where the landward limb of this syncline has accumulated water to a higher level than the seaward limb, the fresh water would in some cases pass below sea level to emerge from the shorter limb.

If the sea is transgressing there is a further departure from the usual condition because the fresh water—salt water surface is brought to a relatively lower position near the shore and there may even be an extension of the fresh water zone out under the

shore where certain stratigraphic and structural conditions prevail which will not be detailed. But in general, however, the limiting surface between the underground fresh water and salt water (admitting that his is a transition zone rather than a clear cut surface) is found higher and higher above sea level as the land surface is found higher. The gradient is, however, less than that of the surface.

When ascending waters meet the lower limits of the zone of descending water they are, of course, deflected laterally and move with the descending water, to appear as obvious springs or less active points or lines of seepage.

The water of the polders is not more salty than it is because the proportion of ascending water to the rainfall and the spring or seepage waters of meteoric origin is too small.

The surface, or rather the transition zone of demarcation between the prevailingly descending waters and the prevailingly ascending waters may be taken roughly as the surface below which the water is characterized by being at least as dense as sea water and having roughly its characteristic ratio of chlorides to carbonates. Dense waters which are of recent origin as opposed to waters of deposition being high in carbonates and low in chlorides.

This surface is by no means near sea level, and is more nearly parallel to the topographic surface. The most significant fact is that the commercial oil and gas deposits are nearly all well beow it.

The causes of the variation of the depth to this surface are four, and are worthy of consideration, since oil and gas above salt water level are found to be largely dissipated. These factors are (a) topography, (b) dip, (c) faults, (d) diffusion.

Where the dip is slight and the topography highly dissected, fresh water will be found down to a surface partly determined by the elevation of the surface of the bed rock in the floor of the valleys. Where the dip is great, but the slope is in the same direction in similar degree, dissected topography will be likewise effective.

But where the dip is against the slope, dissection becomes increasingly less able to cut the bedding planes and so set up circulation, except near the outcrops of these bedding planes. Under these circumstances, the depth to salt water is less, and we find this condition, for the main part, in the Mid-Continent field where shallow oil and gas and salt water is common.

The role of faults is somewhat similar to dissection. Faults which are down dip from outcrops of a porous bed and especially those which are also down slope so that the fault is more likely to extend to the bed are very effective in opening a path of circulation, and hence giving fresh water to a greater depth.

Structural basins which have a thick, widespread, porous sandstone bed, the outcrop of which is lower on one side than on the other, are effective carriers of fresh water to unusually great depths. This tilt of the sandstone basin establishes so active a circulation as to freshen even an enormous bed which was originally salt water filled. On the other hand, if a great sandstone structural basin had an outcropping rim which was nearly of the same elevation on all sides (a rare condition), it is quite probable that if there were no faults, the water, if originally salt, might well remain salt except near the outcrops.

This raises the question of diffusion. Given a gentle dip in a lens, exposed only at one line of outcrop at its upper side, to what depth could mere diffusion freshen this water? Observations are greatly needed at this point. From the meager data available, diffusion seems to be limited where a definite circulation, set up as previously described, is absent. Thus fresh water does not extend to great depths on the flanks of the Arbuckle or Wichita Mountains where steep dips carry, under cover, widely porous sandstones which do not emerge at lower levels to be breached, thus establishing circulation.

It is true that a large deposit of continental sandstone filled with fresh water, and later covered by a transgressing sea, may be reworked only in the upper portion. Under these conditions the transition zone between the overlying salt water and the underlying fresh water is so extensive that diffusion may be expected to be fully effective, except where a lens of continental

sandstone filled with connate fresh water was buried and bounded by continental clay before the transgression.

There remains to be considered continental deposits which have never been transgressed by the sea. Here, of course, the depth to salt water is a maximum (excluding salt lake deposits). The deeper water in such deposits when not salty is often more highly alkaline than at the time of deposition, mainly because of solution of material subsequent to its deposition, facilitated by migration.

We have so far considered the extent to which the fresh water can penetrate, as it is the more variable determinant of the fresh water-salt water surface. However, we must next turn to a consideration of the ascending waters. Let us briefly review the causes of this ascension:

1. The compacting by accumulation of overburden which drives the water as already mentioned.

2. The increasing temperature as a water-filled rock subsides, causing an expulsion because of the resulting greater expansion of the water than of the containing rock.

3. The expulsion by the formation of gas which coal analyses prove to have taken place, which requires a great increase of volume as compared to the material from which it was formed.

4. The expulsion of water owing to replacement by accumulating cement in the pores.

5. The expulsion of the pore contents from the rocks at great depths by the closing of these pores by rock flowage, even though some of this content is taken into rock solution.

6. Occasionally expulsion by an igneous intrusion.

Now observe that these forces are set in motion at least in part by a subsiding land. It is, therefore, under such conditions that the ascending waters are most active and most competent to keep the salt-fresh water at its highest level.

When a land mass becomes stationary, there is still the gradually accumulating overburden off shore giving the above results, which affect in some degree the water below the shore lands. It

is only in lesser areas of the land surface that there is not a degradation which would lead to restriction, cessation, or in one instance, reversal of the foregoing causes of ascending waters. Ascension of water becomes, therefore, much less active or in some cases arrested when subsisdence ceases.

Considering next a land surface which is slowly subsiding, but as yet far from the sea, in this case the transition zone between the fresh and salt water gives way but little from its former position, owing to the lack of opportunities for downward movement of the meteoric waters, as the rock pores are not only already filled with either liquid or gas, but usually have their liquid or gas at higher than hydrostatic pressure.

This last statement is based partly on the fact that previous statements of agreements between theoretical hydrostatic pressures and observations have erroneously used the specific gravity of the water at the bottom of the well for the entire column, whereas the density above this point is, for a part of the column, much less. An additional error is the use of the height of the nearest outcrop, which is not always the outcrop of the freest path, but only of its horizon, and even if so, is not always the lowest outcrop. This may be found at a greater distance, in a different direction. Descending water cannot thrust itself into regions of higher pressure than that exerted by its own weight.

We conclude then that (a) the transition zone between fresh and salt water is at various depths as determined by various agencies, and that it marks the dividing surface between the zone of descending water, and the more slowly ascending waters, which are driven upward by the various agencies described. (b) The surface separating ascending and descending waters is not approximately at sea level, nor a surface having a regular gradient to sea level, but is on the whole more nearly related to the present land surface than to the sea level.

It is not my purpose here to work out the bearings of this position on the accumulation of oil and gas, but rather to try to lead such efforts to avoid the assumption which seems to the author dangerous, that most subterranean waters above sea level are descending, and to offer the foregoing contentions as an aid in developing the very important hydraulic factor on the soundest lines.

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